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The macroeconomic implications
of rising defence expenditure**

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Abstract

European countries plan to boost their defence capabilities to deter external security threats. This implies a substantial change in the volume and composition of fiscal expenditure, as well as the structure of the industrial base. We analyse the macroeconomic implications of alternative policy choices to boost national security. We augment a global dynamic general equilibrium model to include a public good role for defence capabilities, a defence industry with R&D externalities, trade in military equipment, and public investment in dual-use goods. We show that rising security concerns can reduce all forms of economic activity. Enhancing defence capabilities mitigates this effect and boosts aggregate output (GDP) through increased defence industry production and government value added. However, this reorientation leads to a permanent crowding out of private consumption and a minimal effect on CPI inflation, unless the shock is temporary.

JEL classification: E62, F41, F52, H56.

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Non-technical summary

Members of the NATO alliance, including many European countries, have agreed to a large permanent increase in defence spending targets. The scale and scope of this expenditure increase are unprecedented. In this paper, we analyse the macroeconomic implications of the expenditure types involved in meeting the new targets. We augment a state-of-the-art global model to provide a clear connection between defence spending, military capabilities and effective deterrence from external security risks. Greater expenditure on military equipment, personnel and dual-use infrastructure (e.g. sonar technology) boosts defence capabilities and increases deterrence.

When deterrence is sufficiently high, security risks play no role whatsoever in economic decision making (specifically, spending and investment decisions). However, if the level of deterrence falls, either due to a rise in external security risks or due to a fall in defence capabilities, security concerns play a role in these decisions. This effect is non-linear; the further deterrence is from the desired level, the more it affects behaviour. There is also an important asymmetry in the impact of defence expenditure; defence capabilities above the required level of deterrence provide very little additional benefit. To capture international interdependencies in security provision, we assume that European deterrence is the sum of own capabilities as well as those of the US. This allows us to analyse changes in the share of deterrence provided – for example, a reduction in the US share being offset by an increase in the European share.

We analyse a gradual (over ten years) but permanent increase in government defence spending consistent with the NATO-agreed targets. This amounts to an annual expenditure of 5% of GDP, of which 3.5% is defence-specific and the remaining 1.5% is on dual-use goods and services. Given the current levels of European defence spending, this amounts to a permanent increase of slightly more than 1% of GDP of spending on equipment, a double-digit percentage increase in the number of military personnel, and a 0.9% of GDP increase in dual-use investment. Domestic production of military equipment leads to knowledge spillovers from defence R&D activity to other sectors of the economy. Dual-use investment boosts the public capital stock, reducing costs and boosting productivity of private firms who can utilise this infrastructure. An important assumption underlying our analysis is that these policy changes are fully credible (i.e. the spending increases is truly permanent, and implementation occurs as planned).

We find that government spending on defence-related items boosts GDP in the short and in the long run, regardless of the spending component increased. This increase in output is often an artifact of the way this type of spending is recorded in the national accounts. This issue is especially acute for the case of an increase in military personnel. In all cases, there is a crowding out of private consumption, and households, who are now poorer, increase their labour supply (i.e. the number of hours they are willing to work). Despite this, the reallocation of resources facilitates mostly the production of goods and services that only governments can purchase (and households cannot consume). Although this expenditure reorientation increases prices in the economy (i.e. the GDP deflator), it does not lead to an increase in CPI inflation, as these goods are not consumed by households. If the spending increase is temporary, however, there is a persistent increase in CPI inflation and the GDP deflator.

Given the different implications for inflation, we examine in detail the main differences between permanent and temporary shocks. Private consumption and investment fall on impact when defence spending increases are temporary due to

households' desire to smooth deviations from the current level of consumption. This implies an increase in the return on capital. Since this makes up part of firms' marginal costs, there is a rise in inflation as firms raise prices to pass through cost increases. In contrast, a permanent shock implies a new, lower, level for private consumption. Instead of smoothing this fall, households decide to supply more labour to boost their income. They also reallocate a larger share of their resources to investment, a higher level of which is now required to match the long-run increase in labour in production. This reduces the return on capital, and therefore marginal costs and inflation.

The results described above are qualitatively robust to a range of assumed values for the size of defence R&D spillovers and the productivity of dual-use investment. Quantitatively, a stronger role for these channels somewhat mitigates the negative effects of defence spending on private consumption.

1 Introduction

Russia's invasion of Ukraine has prompted a re-assessment of European defence capabilities necessary to serve as an effective deterrent to security threats. At the same time, the United States have pushed for greater burden sharing of deterrence provision. NATO alliance members have committed to a substantial increase in "core defence requirements and defence- and security-related spending" (NATO, 2025). Achieving an annual target of 5% of GDP by 2035 will have significant macroeconomic implications, even if there is a phased approach to meeting this goal.¹

While the high-level aims are clear, there are scant details regarding implementation plans. How will militaries increase the number of available personnel? Through competitive wages, or through conscription? How much of the increased expenditure on equipment and dual-use goods will boost infrastructure and R&D activities? Given that only a limited number of countries have meaningful defence industries, where will these goods be produced? How should governments finance this additional expenditure? And why do defence capabilities affect economic behaviour?²

We examine some of these issues, focusing on the euro area, by adding several novel features to an otherwise standard global dynamic general equilibrium model. We motivate a need for defence capabilities to serve as a deterrent to external security threats. We argue that a sufficient level of deterrence, which we define later, facilitates a smooth functioning of economic activity. In this case, external threats play no role in decision making. However, if defence capabilities are lower than required, an increased probability of damage to the existing and future capital stock in the event of an armed conflict reduces incentives to invest.

A combination of expenditure on military equipment, personnel, and dual-use goods determines the size of the defence capability of a country (and therefore the effectiveness of the deterrent).³ Importantly, in the euro area, the size of the deterrence is a combination of the regions' and the US' defence capabilities. This feature allows us to capture international interdependencies in security provision, such as amongst NATO members.

A defence sector, utilising domestic labour and (private and public) capital produces defence equipment (e.g. arms). Military equipment is tradable, but only purchasable by governments. Defence firms have some market power due to the differentiated nature of their products, and therefore are able to set prices for their goods in domestic and foreign markets. The production of military equipment generates an R&D externality that potentially benefits the other sectors of the economy. Crucially, this externality is linked to the (domestic) production of military equipment and does not apply to expenditure on arms imports.

¹Members are to allocate 3.5% of GDP to an "agreed definition" of defence expenditure, and the remaining 1.5% of GDP to "protect critical infrastructure, defend networks, ensure civil preparedness and resilience, innovate, and strengthen the defence industrial base." They are also to submit annual plans to NATO showing a "credible, incremental path" to reaching this target.

²See Ilzetzki (2025) for a comprehensive discussion of the economics of defence buildups.

³Although increased expenditure does not automatically translate into greater military capability (Antonova et al., 2025), our assumption mimics NATO "capability" targets that focus on defence expenditure to GDP ratios. Given the difficulty in mapping defence "inputs" into "outputs" (Hartley and Solomon, 2015), we believe this is a reasonable approach.

Governments can invest in dual-use goods. The stock of such goods is available to all sectors of the economy, which generates a small, but positive externality in production. Unlike for defence equipment, the externality from dual-use goods depends on the location of expenditure rather than the location of production. Finally, governments also decide on the size of the military personnel that depends on either hiring professional soldiers or via conscription. We distinguish between these two cases through the wages they receive: professional soldiers receive the average wage of the economy, while conscripts only receive a subsistence payment.

We simulate the dynamic response to an increase in euro area of (i) military equipment, (ii) military personnel, and (iii) dual-use investment required to fulfill NATO targets. We provide a careful calibration of the model, with one novel feature being an extension of work conducted by the Stockholm International Peace Research Institute to provide a time series of trade in military equipment for the period 2001-2020 in financial rather than unit terms. This allows us to assess the extent of bilateral arms trade flows, which are crucial in governing the dynamic response of the model.

We find that a decrease in deterrence, induced by a reduction in the US contribution to European defence capabilities, leads to a drop in all forms of economic activity. Output (in all sectors), consumption, investment, imports and exports all decline, dragging down wages and inflation.

A permanent increase in defence equipment spending in Europe significantly enhances military capabilities. This change boosts aggregate output (GDP) through both the depreciation of the growing equipment stock and increased defence industry output, necessitating a reallocation of resources from other sectors. In the long run, the accumulation of R&D from arms production drives further output growth. Inflation falls initially due to an exchange rate appreciation, but later rises due to wage increases. This effect, however, is somewhat attenuated by the positive effect on supply capacity from the increase in R&D.

An increase in military personnel through professional recruitment leads to greater government value added and a boost in defence capability. However, this increase results in a long-term decline in private sector output due to labour shortages, pushing up wages and reducing productive capacity. While inflation may fall slightly in the short run due to exchange rate appreciation, the GDP deflator rises in the long run due to increased government spending on military wages.

A permanent increase in investment in dual-use goods, a key component of the new NATO expenditure targets, provides only a minor boost to defence capabilities. This positive impact arises from increased productivity in the defence industry, leading to a rise in output with minimal inflationary costs. While consumption decreases, the decline is less severe compared to investments solely in defence equipment, and private investment increases significantly due to the broader applicability of capital from dual-use investments. Wages rise as more public capital accumulates, and the R&D stock increases due to positive spillovers from defence sector production. Although inflation initially falls due to an exchange rate appreciation and lower import prices, it remains stable in the long run due to the benefits of increased public capital and R&D. This increased activity leads to a mild rise in the GDP deflator.

Literature Our study sits within the burgeoning field of geoeconomics (Mohr and Trebesch, 2025), in particular the analysis of the effects of geopolitical risk on the macroeconomy (Caldara and Iacoviello, 2022). This literature has thus far focused

on empirical estimates of changes in the degree of geopolitical risk (as proxied by constructed indices, for example).

Our analysis, instead, focuses on examining alternative policy choices to enhancing defence capabilities in a structural macroeconomic model. In that sense, it is related to a specific form of geopolitical risk: the need to deter external security threats and reduce the possibility of a potentially very costly war (see Federle et al. (2026)). Ramey and Shapiro (1998) explore factor reallocation, calibrated to changes in defence spending during the Korean War, with costs for capital movement. They find that consumption, wages and manufacturing productivity fall in response to a military build up. Hendrickson et al. (2018) develop a model where capital accumulation creates a defence externality, whereby countries must deterrence costs are increasing in wealth. This mechanism gives rise to a positive long-run relationship between military expenditure and private production.

Torres (2020) finds, using a DSGE model calibrated to the US, that private consumption and defence services are complements. Adema et al. (2024) utilises an OLG model to analyse various scenarios for implementing conscription in Germany, and find that it reduces private consumption. This fall is largely from the reduced wages of conscripts. Valaitis and Villa (2025) develop a framework wherein a central planner can endogenously mitigate the risk of a disaster, and the damage if does occur, by preemptively investing in defence capital stock to provide a deterrence.

The starting point of our analysis is a reduction in the share of European deterrence provided by the US. In this sense, our work relates to the recent literature on the role of hegemony in the global economy. For example, Clayton et al. (2023) note that countries seek to use their strength to coerce partners and help them achieve geopolitical or economic goals. Broner et al. (2025) show that hegemony promotes policy alignment and that this facilitates deeper trade integration. Meanwhile, Pflueger and Yared (2024) explore the role government financing in providing an military advantage over a geopolitical rival.

The framework we use accounts for the fact that government spending is not on homogeneous goods, but rather on a number of different goods produced by different sectors (Cox et al., 2024). This implies different aggregate economic effects depending on the composition of spending and resulting changes in relative prices. This is in line with the work of Antonova et al. (2025), who demonstrate the importance of persistence in military spending as a signal of sustained future demand. This encourages firms to undertake investments and capital reallocations that might otherwise seem too costly in the short term. However, by raising prices in anticipation, it reduces the macroeconomic benefits on impact.

Our paper also relates to the more broad literature on the economic effects of directed technical change (Acemoglu, 2002) and externalities from knowledge spillovers (Romer, 1986; Lucas, 1988). Benigno and Fornaro (2018) and Anzoategui et al. (2019), for example, show that demand-induced investments can lead to medium- to long-term productivity gains. Ilzetzki (2024) uses aircraft production during the second world war as a case study for “learning by necessity”. Leeper et al. (2010) demonstrate the importance of public capital productivity in the macroeconomic effects of a fiscal stimulus, with Antolin-Diaz and Surico (2025) noting the particular importance of military spending that shifts the composition of public expenditure toward R&D.

Overall, our paper attempts to provide a framework for a more structural analysis of increasing European defence capabilities, that captures the unique features of this

type of economic activity. The outline of the paper is as follows. Section 2 provides an overview of the model and the novel features we introduce related to defence. Section 3 provides details on the calibration of the model and we present the results of our simulations of permanent shocks in Section 4 and contrast them to temporary shocks in Section 5. We provide some concluding remarks in Section 6.

2 Model

To model the various channels through which the government spending on defence affects the economy, we start from a standard New Keynesian global multi-country open economy model that is used in a number of central banks in the Eurosystem, and augment it with the additional features that capture the main channels of defence production, spending, and trade. The model we extend is called the EAGLE (Euro Area and the Global Economy, see Gomes et al. (2012)), a global dynamic general equilibrium model of the euro area and the global economy, and we extend it in several dimensions. First, we augment the model to include a defence industry distinct from the traded and non-traded sectors.⁴ This sector produces military equipment, or arms, which is a tradable good that is purchased by governments only. This has an important implication that the price of these goods does not directly affect the consumer price index (on which monetary policy is based), so that the central bank does not react to price increases in defence industry.

Second, defence equipment production creates an R&D externality which affects all other sectors of the economy. This externality depends on the current and past production of military equipment and is accumulated (and decumulated) gradually, so it has a long-lasting effects, consistent with the findings in Antolin-Diaz and Surico (2025). Third, we add military personnel, which can be either conscripted or employed at a competitive wage. In both cases, this implies a reduction in the labour force available to the private sector, and therefore creates labour shortages that tend to increase wages in the economy. Fourth, we add “dual-use” investment, modelled as public investment, but with a relatively low productivity to account for the fact that this is not necessarily public investment that is strictly needed for the private sector. Nevertheless, this investment boosts public capital, which has also a positive externality on all private sectors, including the defence industry and its associated externality. This interaction is important especially over longer time horizons. Finally, we model a “deterrent” as the number of military personnel combined with the stock of military equipment and dual-use goods, which boost national security by deterring foreign aggression. We discuss each of these novel additions in more detail below.

The remainder of the model is a standard New Keynesian model with sticky prices and wages. Of the four regions in the world economy, two (Germany and the rest of the euro area) constitute a monetary union. This means that they share the same nominal interest and exchange rates, determined by area-wide aggregates. The structure of each regional economy is symmetric and linked with each other through bilateral trade and

⁴More specifically, we build upon a version of the model that contains a non-zero import content of exports (Brzoza-Brzezina et al., 2014) and an extended government sector (Clancy et al., 2016). To save space, we provide only a brief overview of the main features of the EAGLE and instead focus on the addition of the defence industry. We refer the reader to Gomes et al. (2012) for details on the original model framework.

participation in international financial markets, facilitating a comprehensive treatment of the macroeconomic interdependences and spillovers.

Two types of households populate each region, differentiated by their ability to participate in asset markets. Ricardian (I-type) households may transfer their wealth intertemporally by holding money, trading bonds and accumulating physical capital. However, the remaining (J-type) households are liquidity constrained and so are hand-to-mouth consumers (i.e. they spend all of their disposable income). We assume that labour markets are monopolistically competitive, and thereby households act as wage setters for the differentiated labour service they supply to firms. This market power allows for the introduction of nominal rigidities in the labour market. We model wage rigidities using the Calvo (1983) framework, with wages for those households who cannot reoptimise during a given period augmented with an indexation scheme that links changes in pay to past and steady-state consumer price inflation.

There are two layers to the goods market. An intermediate sector produces both tradable, nontradable and defence goods. Monopolistically competitive firms produce these goods, using labour and capital services supplied by households. They set prices for their differentiated output according to the Calvo-type scheme with indexation. Tradable intermediate goods are subject to international trade, with export prices denominated in the importing country's currency (i.e. we assume local currency pricing), and we assume the same framework for defence goods (i.e., local currency pricing). A final goods sector contains perfectly competitive firms who aggregate different varieties of domestic nontradable, tradable, imported and defence goods. The aggregation of imports into a homogeneous import good is subject to adjustment costs, in order to replicate the stickiness of a region's international trade linkages.

The fiscal authority (government) generates revenue through the imposition of both distortionary and lump-sum taxes, as well as seigniorage earned on outstanding money holdings. They use these funds to purchase final goods, including military equipment and dual-use goods, and make transfer payments to households (including salaries of military personnel). The two types of households experience an uneven distribution of transfers and lump-sum taxes, with those having full access to asset markets receiving less and paying more in per-capita terms. Any increase in the fiscal deficit leads to a rise in the stock of government bonds, with a long-term target debt level achieved via a smooth adjustment in lump-sum taxes. The home and the REA blocs share a monetary authority (central bank) reflecting their status as members of a common currency area, with the two remaining regions having separate monetary authorities. All regions follow a Taylor-type interest rate feedback rule, which is specified in terms of deviations of consumer price inflation and output from their target (i.e. steady state) levels and allows for interest rate smoothing.

2.1 Deterrence from defence capabilities

We proxy the amount of deterrence D_t provided by governments with their expenditure on defence capabilities, a composite of dual-use goods, military equipment and personnel:⁵

⁵This is in line with NATO capability targets, which focus on defence expenditure to GDP ratios. However, Ilzetzki (2025) notes that this is “economically problematic”. Antonova et al. (2025) find that an increase expenditure does not automatically translate into greater military

$$D_t = K_{G,t}^{\alpha_G} E_{D,t}^{\alpha_{DD}} N_{M,t}^{1-\alpha_{DD}} \quad (1)$$

where $K_{G,t}$ is the dual-use capital stock, $E_{D,t}$ is the stock of military equipment:

$$E_{D,t} = (1 - \delta_E)E_{D,t-1} + G_{D,t-j} \quad (2)$$

$N_{M,t}$ is military personnel (described later) and α_G and α_{DD} are the share of deterrence provided by the dual-use capital and defence equipment stocks respectively. Given that delivery of arms is often subject to relatively long delays (Burilkov et al., 2025), we allow for time-to-build in the military equipment accumulation process. We measure this with the index j in $G_{D,t-j}$, which tells us how many quarters it takes to receive delivery of a paid unit of equipment.

One important characteristic of defence capability is that it is only a potential service provided by the government. Therefore, the provided service does not count towards GDP. Only the cost components, the total wage bill of military personnel, $G_{MW,t}$, and the depreciation of defence equipment, $\delta_E E_{D,t-1}$, enter the national accounts (as gross value added of the government sector). As the production of defence capabilities directs resources away from private uses, there must be a motivation for incurring such expenses.

We argue that a sufficient level of defence capabilities serve as a deterrent to external security threats. By maintaining deterrence at its desired level, the government facilitates a smooth functioning of economic activity and security risks play no role in decision making. However, if defence capabilities are lower than required, security concerns can impact household's investment decisions. The size of this effect is non-linear, with households adjusting their behaviour more rapidly the further defence capabilities fall from their expected level. We incorporate this feature using an exponential function in the deviation of D_t from D_{min} , the minimum level of deterrence required to avoid security concerns.⁶ We next describe how we operationalise this channel in the model to affect investment.

Before doing so, it is worth emphasising that our model setup focuses entirely on the economic implications of maintaining a sufficient level of deterrence to mitigate external security risks. We do not consider an escalation beyond this to a state of war. This would involve introducing many additional (and non-standard) features to our framework. These include goods rationing and price controls, as well as import and export restrictions.

Our approach comes with an implicit downside bias, in the sense that the “reward” for maintaining a sufficient level of deterrence whereas letting this fall below the required level results in worsening economic activity. Essentially, defence capabilities

capability, as additional funds lead to rising prices rather than augmented defence capacity. Federle et al. (2024), in contrast, provide empirical evidence that a surge in military spending following an increase in government revenues greatly boosts a participants' odds of winning a war.

⁶This is similar in spirit to Erceg et al. (2024)'s approach of proxying state dependent price and wage setting using a function of the geometric lag of past inflation rates. The asymmetric nature of our function, whereby behaviour is only affected by deviations *below* the desired level of deterrence, is similar to those used for the analysis of bank capital regulation (Clancy and Merola, 2017; Lozej et al., 2023).

are developed in the hope that they are never actually required. As such, the resources allocated to defence represent a form of insurance that, in our case, is not called upon.

2.1.1 Security and private investment

We assume that with insufficient defence capabilities, there is a chance that part of the existing and future (private) capital stock is damaged by an attack and therefore produces less than anticipated. The capital accumulation equation becomes:

$$K_{t+1} = [(1 - \delta)K_t + (1 - \Gamma_{I,t})I_t] \phi_{I,t}, \quad (3)$$

where K_t is the current stock of capital, $\Gamma_{I,t}$ are investment adjustment costs, I_t is investment, and δ is the capital depreciation rate.⁷ What is new in our setup is $\phi_{I,t}$, which is the probability that next period's capital stock is unaffected by an attack (i.e. is not damaged), and is defined as:

$$\phi_{I,t} = \Phi_{I,t}(\phi_W + \psi_I D_t^{CO}), \quad (4)$$

where $\Phi_{I,t}$ is the normal cumulative density function, D_t^{CO} are the country CO 's defence capabilities, and ϕ_W is the parameter that regulates the steady-state level of the damage probability and ψ_I regulates the intensity of response to the change in the defence capabilities.⁸

Given the properties of the cumulative density function, its derivative is very close to zero when defence capabilities are sufficient and $\phi_{I,t}$ is close to one. In this case, even a significant increase in defence capabilities does not bring additional benefits in terms of greater security for the accumulated capital. However, a material reduction in defence capabilities would reduce $\phi_{I,t}$ to below one and would bring it to the region of the function $\Phi_{I,t}(\cdot)$ where fluctuations in defence capabilities in either direction matter.

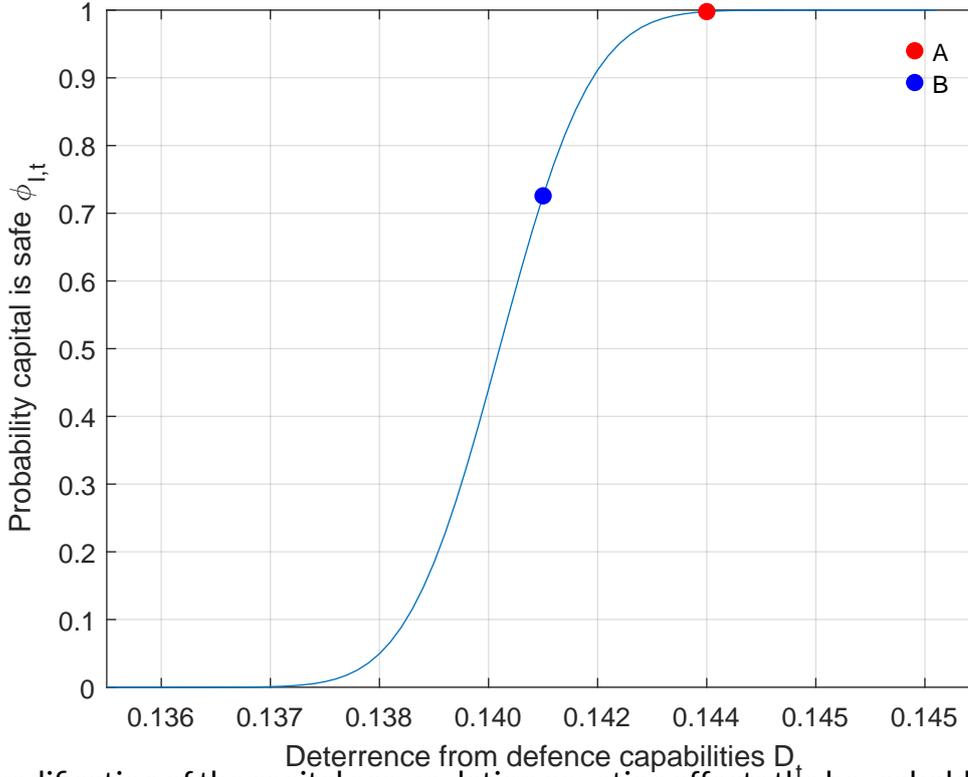
We provide a graphical illustration of this concept in Figure 1. The y-axis represents $\phi_{I,t}$ and the x-axis represents the level of deterrence. We calibrate ϕ_W such that $\phi_{I,t}$ is very close to 1 in the steady state, represented by point A. This implies that deterrence is sufficiently high and security concerns are not a factor in investment decisions. It also shows that a rise in deterrence over and beyond the desired amount will not have any effect on behaviour. A fall in deterrence, due to a reduction in US provision of defence capabilities for example, would see a movement down the curve towards point B.⁹ It is clear that, when deterrence is near its desired value, a reduction does not have a very large effect on the probability of the capital stock incurring damage. It is only when the gap to desired deterrence becomes large(r) that further changes imply a need to factor security risks into investment decisions.

⁷The investment adjustment cost function $\Gamma_{I,t}$ takes the standard quadratic form: $\Gamma_{I,t} \equiv \gamma_I/2(I_t/I_{t-1} - 1)^2$, where γ_I is a parameter.

⁸Note that the model nests the standard approach i.e., when $\phi_{I,t} = 1$, the capital accumulation equation is identical to models such as Smets and Wouters (2007).

⁹An increase in the defence capabilities in the rest of the world would result in a shift of this curve to the right. Assuming no change in European defence capabilities, this would essentially result in the same effect as a downward movement along the curve: a rise in security concerns due to an insufficient level of deterrence.

FIGURE 1. Effect of level of deterrence on investment decisions



Our modification of the capital accumulation equation affects the households' first order condition for investment and the price of capital goods (Tobin's q):

$$P_{I,t} = \phi_{I,t} \left[Q_t z_{I,t} (1 - \Gamma_{I,t} - \Gamma'_{I,t} I_t) + \beta \frac{\Lambda_{I,t+1}}{\Lambda_{I,t}} Q_{t+1} z_{I,t+1} \Gamma'_{I,t+1} \frac{I_{t+1}^2}{I_t} \right], \quad (5)$$

where $P_{I,t}$ is the price of investment goods (measured in terms of consumption goods), Q_t is Tobin's q (detailed below), $\Gamma_{I,t}$ and $\Gamma'_{I,t}$ are investment adjustment costs and its derivative, respectively, $z_{I,t}$ is an investment technology shock, and $\Lambda_{I,t}$ is the marginal utility of Ricardian households (who own capital assets in the economy). The first-order condition for capital is:

$$Q_t = \beta \frac{\Lambda_{I,t+1}}{\Lambda_{I,t}} \left[\phi_{I,t+1} (1 - \delta) Q_{t+1} + (1 + \tau_{t+1}^K) (R_{K,t+1} u_{t+1} - \Gamma_{u,t} P_{I,t+1}) + \tau_{t+1}^K P_{I,t+1} \right], \quad (6)$$

where τ_{t+1}^K is the capital income tax, u_t is capital utilisation rate, and $\Gamma_{u,t}$ is the capital utilisation rate adjustment cost.¹⁰

A similar modelling device as above could be used to analyse the effects of potential complementarity of publicly-provided defence good and private consumption, but this would unnecessarily add further complexity to the model (while the earlier version of the paper had this feature, the channel was relatively weak compared to the investment channel described above).¹¹

¹⁰The utilisation adjustment cost is also quadratic, $\Gamma_{u,t} \equiv \gamma_{u1}(u_t - 1) + \gamma_{u2}/2(u_t - 1)^2$, where γ_{u1} and γ_{u2} are parameters.

¹¹The modelling approach used was similar as in Clancy et al. (2016), where consumption in the utility function is a constant-elasticity of substitution aggregate of private consumption and

2.2 Government spending

We assume government spending on defence is exogenous (i.e., it is a decision of the government). The government can use its funds to purchase defence equipment, hire military personnel, or invest in dual-use goods. In all cases, the government finances its spending by issuing debt, with a fiscal rule specified in terms of lump-sum taxes on Ricardian households. We outline the government spending options in more detail below. In all other respects, the government budget constraint is standard: it collects consumption, labour and capital taxes, issues a riskless bond, and spends - in addition to the aforementioned defence spending - on other non-defence government consumption (see e.g. Gomes et al. (2012)).¹²

2.2.1 Defence equipment production

The domestic production of tradable military equipment utilises private and public capital as well as private labour:¹³

$$Y_{D,t}^S = z_{D,t} K_{G,t}^{\alpha_G} (K_{D,t}^D)^{\alpha_D} (N_{D,t}^D)^{1-\alpha_D} - \psi_D \quad (7)$$

where, $Y_{D,t}^S$ is defence sector output, $z_{D,t}$ is the level of productivity, α_G determines the productivity of public capital $K_{G,t}$, $K_{D,t}^D$ is rented private capital, $N_{D,t}^D$ is hired private labour, α_D is the capital share in the defence sector and ψ_D represents sector-specific fixed costs of production.

There are two externalities in this formulation. The first, consistent with the empirical findings of Antolin-Diaz and Surico (2025), captures the positive R&D spillovers from defence good *production* on other industries.¹⁴ We formalise this notion by directly linking the level of defence equipment production to the productivity of the aggregate economy. One can think of this as a form of “learning by necessity” (Ilzetzki, 2024), whereby an increase in demand beyond existing capacity constraints induces

government-provided deterrence, with the modification that the weight of the deterrence in the aggregate increases when deterrence falls. The results are available upon request.

¹²We do not model government spending for various purposes as an optimal choice subject to a welfare function.

¹³We assume all defence goods are tradable and are only purchased by governments. We therefore neglect equipment production for potential purchase by private security companies or individuals. This share is very small compared to defence equipment purchased by governments. Even though there are likely some military goods that are so advanced that the producing country would not be willing to sell them, these are in principle tradable.

¹⁴In contrast, Fieldhouse and Mertens (2023) argue that knowledge spillovers from defence and nondefence R&D are likely quite different. They reason that access to knowledge gained from military R&D work is often restricted from the public to maintain military superiority, thereby limiting spillovers. Therefore, they focus their analysis on non-defence R&D expenditure.

productivity growth.¹⁵ Concretely, we assume that the stock of R&D stemming from defence equipment production evolves according to a law of motion:

$$A_{D,t} = (1 - \delta_A)A_{D,t-1} + \zeta_D Y_{D,t-h}, \quad (8)$$

where $A_{D,t}$ is the accumulated know-how in defence production that depreciates (i.e. becomes obsolete) at the rate δ_D and increases proportional to the level of the defence sector production by a fraction ζ_D . This latter term reflects the fact that only a small fraction of production is linked to R&D activities. Moreover, we allow for a delay of h periods before knowledge generated from R&D spills over to other sectors of the economy. Therefore, the accumulated knowledge creates a positive externality $z_{D,t}$:

$$z_{D,t} = A_{D,t}^{\gamma_D}, \quad (9)$$

where γ_D is a parameter that measures the efficiency of knowledge transmission arising from the defence equipment production externality in the traded ($Y_{T,t}^S$) and non-traded ($Y_{NT,t}^S$) sectors:

$$Y_{T,t}^S = z_{D,t} K_{G,t}^{\alpha_G} (K_{T,t})^{\alpha_T} (N_{T,t})^{1-\alpha_T} - \psi_T \quad (10)$$

$$Y_{NT,t}^S = z_{D,t} K_{G,t}^{\alpha_{NT}} (K_{NT,t})^{\alpha_{NT}} (N_{NT,t})^{1-\alpha_{NT}} - \psi_{NT}. \quad (11)$$

This formulation is convenient because setting $\gamma_D = 0$ allows us to shut down this externality without altering the model in any other way. Our approach has parallels in the way (negative) externalities are modelled in the economics of climate change literature (Golosov et al., 2014; Nordhaus, 2019; Hassler et al., 2021).

The second externality is an enhancement to private defence firms productivity from the (free) use of public capital stock, accumulated via government investment expenditure. This channel is similar to the knowledge spillovers from R&D activities discussed above. However, a crucial difference is that this externality depends on domestic *expenditure* rather than production. Our inclusion of this mechanism reflects the substantial proportion of NATO expenditure targets focused on products that have both civilian and military uses (i.e. have a “dual-use”). For example, maritime surveillance technologies are useful for national defence, but also search and rescue, environmental protection (e.g. monitoring oil spills and pollution), fisheries management (including tracking illegal fishing activities), and vessel traffic management that could lower transport costs. More broadly, all critical infrastructure such as roads, ports, bridges, railway and energy networks fall within this category.

Note that both externalities reduce marginal costs for firms in all sectors of the economy. We illustrate this for defence firms (all other sectors are symmetric and marginal costs are equalised throughout the different parts of the economy):

¹⁵We consider this a plausible channel for Europe at this current juncture. Although the empirical evidence in Antolin-Diaz and Surico (2025) relates to the US, which has a far more established defence industry, the need to rapidly establish and sustain a credible European defence deterrence may induce the widespread adoption (and ongoing development) of advanced technologies. See Enders et al. (2025) for an assessment of the priorities for a German and European defence policy strategy for the coming decades, with an emphasis on cutting-edge technology requirements. More generally, it is widely recognised that boosting Europe’s growth potential requires substantial investment in advanced technologies (Draghi, 2024).

$$MC_{D,t} = \frac{1}{z_{D,t} K_{G,t}^{\alpha_G} (\alpha_D)^{\alpha_D} (1 - \alpha_D)^{1 - \alpha_D}} (R_t^K)^{\alpha_T} \left((1 + \tau_t^{W_f}) W_t \right)^{1 - \alpha_T} \quad (12)$$

where the parameter $\tau_t^{W_f}$ accounts for labour taxes paid by defence firms, W_t are wages and R_t^K is the rental cost of capital. Both $z_{D,t}$ and $K_{G,t}^{\alpha_G}$ enter in the denominator, so an increase in either component lowers the marginal costs of defence firms $MC_{D,t}$.

These two externalities differ in a crucial way: one depends on the knowledge gained from production, while the other is a function of expenditure. As such, while there is no additional benefit from importing military equipment (because the knowledge generated from the research and development of the underlying technology remains abroad), imported dual-use goods can generate positive externalities for the domestic economy.

Different varieties of defence goods are imperfect substitutes, produced under monopolistic competition. This market power allows firms to set nominal prices in both domestic and foreign markets, with a markup over marginal costs. Only a fraction of firms are able to reoptimise their prices $\tilde{P}_{D,t}$ by maximising the discounted sum of their expected nominal profits:¹⁶

$$\tilde{P}_{D,t} = \left[\sum_{k=0}^{\infty} (\xi_D)^k \Lambda_{I,t,t+k} (P_{t+k}(n) Y_{D,t+k}(n) - MC_{D,t+k}(Y_{D,t+k}(n) + \psi_D)) \right] \quad (13)$$

taking as given demand for their goods (outlined below) and where $1 - \xi_D$ (with $0 \leq \xi_D \leq 1$) is the probability a firm n can reoptimise in a given period and $\Lambda_{I,t,t+k}$ is the stochastic discount factor of I-type households, who own defence firms. Firms that cannot reoptimise adjust their prices according to an inflation-based indexation scheme:

$$P_{D,t}(n) = (\Pi_{D,t-1})^{\chi_D} \bar{\Pi}^{1 - \chi_D} P_{D,t-1}(n) \quad (14)$$

where $\Pi_{D,t-1} = P_{D,t-1}/P_{D,t-2}$, χ_D is the degree of indexation and $\bar{\Pi}$ is the central bank's constant (gross) inflation objective. Sector-specific price indices, therefore, evolve according to:

$$P_{D,t} = \left[\xi_D (\Pi_{D,t-1}^{\chi_D} \bar{\Pi}^{1 - \chi_D} P_{D,t-1})^{1 - \theta_D} + (1 - \xi_D) (\tilde{P}_{D,t})^{1 - \theta_D} \right]^{\frac{1}{1 - \theta_D}}. \quad (15)$$

where θ_D is the elasticity of substitution in the price aggregator.

2.2.2 Defence equipment purchases

We assume only governments can purchase military equipment. They buy these goods from firms that act under perfect competition and assemble final defence equipment bundles Q_t^{GD} that are a composite of domestic tradable HT_t^{GD} and imported IM_t^{GD} defence equipment using a constant elasticity of substitution (CES) technology:

¹⁶Pricing in foreign markets is analogous, apart from the inclusion of the relevant bilateral nominal exchange rate to express prices in exporters' domestic currency. We therefore omit these equations to save space.

$$Q_t^{GD} = \left[\nu_{GD}^{\frac{1}{\mu_{GD}}} (HT_t^{GD})^{\frac{\mu_{GD}-1}{\mu_{GD}}} + (1 - \nu_{GD})^{\frac{1}{\mu_{GD}}} (IM_t^{GD})^{\frac{\mu_{GD}-1}{\mu_{GD}}} \right]^{\frac{\mu_{GD}}{\mu_{GD}-1}} \quad (16)$$

where ν_{GD} is the (quasi)-share of the domestically produced military equipment (i.e. the degree of home bias), and μ_{GD} is the elasticity of substitution between domestic and imported defence goods. Government demand for domestic military equipment is therefore:

$$HT_t^{GD} = \nu_{GD} \left(\frac{P_{HT,t}}{P_{GD,t}} \right)^{-\mu_{GD}} Q_t^{GD}. \quad (17)$$

where $P_{HT,t}$ is the price of tradable goods and $P_{GD,t}$ is the price of final defence goods. Imports of defence equipment consist of a bundle of (bilateral) imports, $IM_t^{GD,CO}$, produced in the other blocs:

$$IM_t^{GD} = \left[\sum_{CO \neq H} \left(\nu_{MGD}^{H,CO} \right)^{\frac{1}{\mu_{MGD}}} \left(IM_t^{GD,CO} \right)^{\frac{\mu_{MGD}-1}{\mu_{MGD}}} \right]^{\frac{\mu_{MGD}}{\mu_{MGD}-1}}, \quad (18)$$

where the bilateral trade shares $\nu_{MGD}^{H,CO}$ sum to one and demand for defence good imports from bloc CO is

$$IM_t^{GD,CO} = \nu_{MGD}^{H,CO} \left(\frac{P_{IM,t}}{P_{IMGD,t}} \right)^{-\mu_{MGD}} IM_t^{GD}. \quad (19)$$

The superscript H indicates the home country and the superscript CO represents the bloc from which the defence good is imported. Again, μ_{MGD} is the elasticity of substitution between them, $P_{IM,t}$ is the price of imported goods and $P_{IMGD,t}$ is the price of defence good imports. We assume that, in the long run, the firm bundling final defence goods allocate their expenditure optimally between defence goods from different regions. They take their relative prices as given, and minimise their expenditure $P_{GD,t}HT_t^{GD} + P_{GD,t}IM_t^{GD}$ subject to the production functions (16) and (18). Prices of the final, $P_{GD,t}$, and imported defence goods, $P_{IMGD,t}$, respectively, are:

$$P_{GD,t} = \left[\nu_{GD} (P_{HTGD,t})^{1-\mu_{GD}} + (1 - \nu_{GD}) (P_{IMGD,t})^{1-\mu_{GD}} \right]^{\frac{1}{1-\mu_{GD}}}, \quad (20)$$

$$P_{IMGD,t} = \left[\sum_{CO \neq H} \nu_{MGD}^{H,CO} (P_{IM,t}^{CO})^{1-\mu_{MGD}} \right]^{\frac{1}{1-\mu_{MGD}}}, \quad (21)$$

where $P_{IM,t}^{CO}$ is the price of imports from bloc CO and the bilateral exchange rate is contained in the bilateral import prices.

We treat the parameters ν_{GD} and ν_{IMGD} as fixed. This implies that the share of imported defence goods and the bilateral allocation of these is governed exclusively by relative prices. In reality, this may not be the case. Governments often decide to purchase defence goods from a particular country, and indeed this feature is embedded in recent agreements amongst NATO member states, as well as the EU-US trade

framework (NATO, 2025). However, these shares were quite stable over the past 20 years (see Appendix B) and so we treat these parameters as constant.¹⁷

Government purchases of defence equipment are set as a fraction of nominal steady-state output, which follows an AR(1) process:

$$G_{D,t} = (1 - \rho_D)\overline{G_D} + \rho_D G_{D,t-j} + \varepsilon_{D,t}, \quad (22)$$

where $\overline{G_D}$ is the steady-state level of defence equipment purchases, $\varepsilon_{D,t}$ is a shock to its level, and ρ_D is the persistence of this spending. Market clearing for defence good purchases requires:

$$G_{D,t} = Q_t^{G_D} \quad (23)$$

and a resource constraint for supply to equal total demand, which can come from the domestic economy or from abroad:

$$Y_{D,t}^S = sa_{D,t} HT_t^{G_D} + \sum_{CO \neq Home} sxa_{D,t}^{CO} \frac{s_{CO}}{s_{Home}} IM_t^{G_D, CO}, \quad (24)$$

where $sa_{D,t}$ and $sxa_{D,t}^{CO}$ are price dispersions on domestic and foreign markets, respectively, s_{Home} is the size of the domestic economy and s_{CO} are the sizes of other blocs, and $IM_t^{G_D, CO}$ are imports by other blocs from the home country.

2.2.3 Defence personnel recruitment

National security is characterised by a high degree of capital-labour complementarity: defence equipment is ineffective as a deterrent without (well-trained) personnel to utilise it. We therefore include in the model a stock of defence personnel $\overline{N}_{M,t}$. Note that these are distinct from employees in private defence firms $N_{D,t}$.

Governments also decide on the wage bill for military personnel, with the size of their defence forces increased by hiring professional soldiers or via conscription. We distinguish between these two cases by the wages they receive: professional soldiers $N_{MP,t}$ receive the (competitive) average wage of the economy w_t , increased by social security contributions $(1 + \tau_t^{WF})$ paid by the government, plus (potentially) a wage premium $(1 + wpr_t)$, while conscripts $N_{MC,t}$ only receive a fraction ϑ of this as a subsistence payment.¹⁸ This results in total military personnel and a military wage bill, respectively, of:

¹⁷To account for the shifts in government defence equipment imports, we could examine the implications of allowing governments to alter ν_{G_D} and $\nu_{IM_{G_D}}$. Such an experiment would be similar to the region-specific discrimination analysed by Clancy et al. (2024) in the context of reshoring production. However, to avoid clutter, we leave this for further work.

¹⁸As such, an increase in military employment does not have a *direct* effect on wages in other sectors. Instead, there is only an indirect effect through the reduction in the amount of available labour for the private sectors, including the defence sector. We could incorporate a direct effect by adding search and matching frictions in the labour market, something previously implemented in the EAGLE framework (Jacquinot et al., 2018). However, this would unnecessarily complicate the model, without altering the qualitative findings. Nevertheless, because of the direct effect on wages is missing, it is likely that the wage dynamics we uncover are at the lower end of possible outcomes.

$$N_{M,t} = N_{MP,t} + N_{MC,t} \quad (25)$$

$$G_{MW,t} = (1 + \tau_t^{WF})(1 + wpr_t)w_t N_{MP,t} + \vartheta(1 + \tau_t^{WF})(1 + wpr_t)w_t N_{MC,t}. \quad (26)$$

Military personnel come from the available pool of workers, and therefore an increase in army recruitment reduces the availability of labour in the other sectors (including the defence industry):

$$N_t = N_{T,t} + N_{NT,t} + N_{D,t} + N_{M,t}, \quad (27)$$

where N_t is total labour, $N_{T,t}$, $N_{NT,t}$, and $N_{D,t}$ are employment in the tradable, non-tradable, and defence sectors respectively. From the above equation it is clear that, for a given aggregate labour supply, any increase in military personnel will create a shortage in other sector's labour markets.¹⁹

2.2.4 Dual-use investment

Government can invest in dual-use goods $I_{G,t}$, which accumulate in an analogous way as private capital and form a stock of dual-use capital $K_{G,t}$:

$$K_{G,t} = (1 - \delta_G)K_{G,t-1} + I_{G,t}. \quad (28)$$

where δ_G is the depreciation rate of dual-use capital. This capital has the property that it enters as a non-rival production factor into the production functions of defence and private sectors (see equations 7, 10 and 11). This can be interpreted as infrastructure that can be used by both private and defence sectors, and we account for the fact that this would be less important than typical government infrastructure investment when we calibrate the model.

3 Calibration

We calibrate the model using a combined approach. First, we calibrate the parameters in the constant-elasticity-of-substitution aggregators of final goods to match the Great Ratios (i.e the shares of consumption, investment, government spending, imports and exports to GDP) in the data. We do the same for bilateral import shares and for the shares of re-exports. See Tables 5 and 7 in Appendix C for details. For the other parameters governing the model dynamics, we use values that are standard in the literature (Christoffel et al., 2008; Gomes et al., 2012). See Tables 6 and 8 in the same appendix.

The novel part of the model is the effect of deterrence on economic decision making, defence sector production and the associated transmission mechanisms, as well as the inclusion of military personnel. We provide details on the calibration of these features in Table 2 and focus the discussion here on these aspects.

¹⁹This would not be the case if labour supply is perfectly elastic, or if the increase in military personnel occurs during an economic downturn and therefore reduced labour demand in other sectors. Our calibration assumes we are not in these situations.

A novel transmission channel in our model is the effect on households and firms induced by reductions in the level of deterrence. We must first define what degree of defence capability is “sufficient” to serve as a deterrent. To do so, we assume that past military expenditure indicates a revealed preference for the necessary level of capabilities. The average defence spending of Germany, the rest of the euro and the US is 0.3%, 1.1% and 3.8% respectively between 2001-2024. As capability is the weighted sum of these regions capabilities, we can compute the share of deterrence that this level of expenditure provides. The US provides by far the largest share, at 78.3%, with Germany providing 5.3% and the rest of the euro area accounting for 16.4% of total defence capabilities.

As we described in Section 2.1.1, our calibration assumes that deterrence is sufficiently high to have effectively no effect on economic behaviour in the steady state. More specifically, we calibrate the probability of the capital stock being unaffected by an attack (i.e. not being damaged) $\phi_{I,t}$ as 0.9999.²⁰ The key element is to outline a plausible response to a change in security risks. For something as intangible as deterrence, it is likely that households ignore minor variations and would change their behaviour only following a large fall below the desired level.

To calibrate the dynamic response of investment and consumption to a rise in external security risks, we utilise evidence provided by the European Commission on the worse-than-expected macroeconomic performance following Russia’s invasion of the Ukraine (EC, 2025). They show that, compared to what was expected in the Autumn 2021 forecasts, annual investment growth was on average two percentage points lower in EU countries during 2022-2023. Consumption growth was just over one p.p. lower. Indeed, all categories except for government consumption were below pre-war expectations. Overall GDP fell by around two percentage points. Notably, as captured by our deterrence functions, this effect is non-linear: countries with closer proximity to the conflict fared worse.

The size of these effects are likely an upper bound for nations not actively involved in a war, and an upper bound in terms of the effect of the level of deterrent, because the shock includes a number of other channels. For example, a major factor in the economic disruption was a large reliance on energy imports from Russia that is now substantially reduced. In addition, any required adjustments following the imposition of sanctions and other (trade and financial) restrictions are included. Therefore, we calibrate $\phi_{I,t}$ such that the negative effects are only a fraction of those reported by (EC, 2025), and follow the intuition that the response of investment should be stronger than the response of consumption, for which we use the calibration of $\psi_I = 2$. Concretely, we pick these numbers to calibrate the strength of responses so that a reduction in the US contribution to European deterrence equivalent to 20 p.p. reduction in the share of the deterrent provided by the US to Europe in the total European deterrent implies a drop in euro area investment and consumption of approximately 0.3 p.p., so that the obtained responses are at the lower end of the magnitudes reported in (EC, 2025). The responses are shown in Figure 3. As calibrated, fluctuations in deterrent level itself play some, but not a crucial role in determining economic fluctuations for our analysis.²¹

²⁰Recall that we could set this parameter to 1 would give us the standard investment equation.

²¹We are acutely aware that the quantification of this channel has only weak empirical support and may be controversial, which is why we keep it weak on purpose. This channel can be easily strengthened or weakened within our framework simply by adjusting the calibration.

We utilise information from the Stockholm International Peace Research Institute (SIPRI) database to calibrate the level of government defence expenditure. Data for calibration of the share of personnel employed in the armed forces (as percent of labour force) comes from The Global Economy.²² Not all military expenditure is on equipment. We assume that half of spending goes on this component, while the other half is for other uses (including the payment of military personnel). In terms of the composition of military personnel, we assume that armies in Europe and the US are fully professional, while the share of conscripts in the RW is 50%.²³

Professional soldiers receive the steady-state average wage of the economy, plus (in some jurisdictions) a wage premium. This premium is potentially significant. In the US, for example, the recommended military wage must correspond to the 75th percentile of comparable civilian pay (i.e. taking into account equivalent educational attainment). Data on US military pay suggests that this premium is even higher than recommended, at the 84th percentile of civilian pay on average in 2016 (see Hosek et al. (2018)). To calibrate this premium, we first pin down total defence spending and differentiate between expenditure on equipment and on personnel. We then match the number of military personnel (as percent of the labour force). From this, we back out the military wage premium to reconcile the share of defence spending on personnel and the number of personnel.²⁴

We calibrate defence equipment production using standard values for the shares of capital and labour (0.3 and 0.7). A novel aspect of the defence equipment production is the R&D “byproduct” that it generates from knowledge generation. We assume that only a small fraction of this production flows into the R&D stock. We set this value to 2%, in line with COFOG data for Europe, where the share of R&D expenditure in total defence spending is typically below 3% of defence expenditure. We assume the productivity of the R&D stock is symmetric to that of the dual-use capital, which we set to 0.01, the lower end of the typical values used in the literature analysing public investment. In our calibration R&D depreciates in 10 years, in line with standard depreciation rates in the literature. In contrast, dual-use capital takes 25 years to depreciate, which is the standard value used for structures. We verify the suitability of this calibration by checking that the response of R&D to a defence expenditure increase matches the pattern from the US reported in Antolin-Diaz and Surico (2025). This shows that there is a persistent increase in output over a medium term following an initial increase in defence-related R&D.

Defence capabilities, which serve as a deterrent to external security threats, depends on the stock of military equipment, the number of military personnel and the level of

²²The source is the website theglobaleconomy.com. The data we use from SIPRI are averages from 2001-2020, i.e. before the Russian invasion of Ukraine and subsequent increase in defence expenditure in many European countries. The data from The Global Economy are for 2020.

²³As noted in Section 2.2.3, conscripts only receive a fraction ϑ of professional soldiers’ salary as a subsistence payment. Therefore, a large(r) share of conscripts effectively represents a wage discount for an average soldier. For example, a 50% share of conscripts is equivalent to military personnel in aggregate receiving half of the average wage in the other sectors of the economy.

²⁴About a third of defence spending in most countries is intermediate consumption or “other”, which do not fit with either personnel or equipment spending. We allocate these items to the two categories in the model, i.e., equipment and personnel, to maintain the proportion spent on these two categories.

dual-use capital goods. To account for the fact that such capabilities are typically more capital-intensive, we set the share of capital at a higher level of 0.5.²⁵

For the calibration of the defence equipment spending allocation between domestically produced and imported goods, we utilise data from SIPRI, which, to the best of our knowledge, is the only consistent database on world trade in military equipment. As the database relies on publicly reported trade, we consider this as a lower bound (i.e. it is quite likely that there is unreported trade). Using this data, we calculate that defence equipment trade accounted for around 0.25% of world GDP between 2001-2020.²⁶ Defence equipment spending, however, is only a fraction of total defence spending. In Europe, total defence spending is typically a bit over 1% of GDP and defence investment spending it is typically around 20% of total defence spending, with an additional 20% spending going for intermediate goods, and about half of defence spending going for personnel. In line with this, we assume that half of defence spending is spent on equipment.

As the share of spending on equipment is smaller than total defence spending, and spending on personnel cannot be traded by definition, it must be the case that a significant proportion of defence equipment is traded. Moreover, such trade is typically among allied states (e.g., NATO countries purchase NATO-compatible equipment). To account for this, we use historic defence equipment trade data from SIPRI to calibrate both the level of trade (through the calibration of total arms exports shares in GDP) and the bilateral arms trade linkages (through the share of arms imports from a particular bloc of countries in the model). To do so, we had to transform the quantity-based arms trade flows in the SIPRI database to value-based trade flows. We describe these calculations, which represent a novelty of our analysis, in detail in Appendix B. We provide the resulting trade matrix in Table 1. This makes the dominant role of the US in bilateral arms trade clear, with all blocs of the model importing their largest share of their arms from the US. We use these shares as targets to calibrate the model parameters related to bilateral arms trade, which we report in Table 2.

TABLE 1. Shares of defence equipment imports from different regions

| Country/bloc | DE | REA | US | RW |
|--------------|--------|--------|--------|--------|
| DE | - | 0.0839 | 0.0948 | 0.0205 |
| REA | 0.2025 | - | 0.1868 | 0.1088 |
| US | 0.6258 | 0.8153 | - | 0.8707 |
| RW | 0.1717 | 0.1008 | 0.7184 | - |

Notes: Source: SIPRI. Averages 2001-2020. Each column reports the share of imports of country/bloc in the heading of the column, from countries/blocs in rows, in total arms imports of the country/bloc in the column. Totals may not add up due to rounding.

²⁵Analysing the implications of a changing structure in the composition of defence capabilities represents an interesting avenue for future research. For example, an emphasis on the use of drones implies an even higher capital share.

²⁶This is the annual average of global military equipment exports in current US dollars. We calculate this using the same methodology as SIPRI used for 2022, divided by global output in current US dollars (taken from the World Bank). Much of the post-2020 data are missing from the dataset.

For the elasticities of substitution between imported and domestically produced defence equipment, we use a moderate value of 1.5 in line with Faruquee et al. (2008). We assume the same value for the elasticity of substitution between imported defence equipment from various regions.

TABLE 2. Defence-related calibration

| | DE | REA | US | RW |
|---|--------|--------|--------|--------|
| Defence spending | | | | |
| % of GDP | 1.21 | 1.52 | 3.92 | 2.00 |
| Share of spending on equipment | 0.50 | 0.50 | 0.50 | 0.50 |
| Military personnel | | | | |
| % of labour force | 0.50 | 1.00 | 0.84 | 1.50 |
| % share of conscripts | 0 | 0 | 0 | 0.50 |
| Defence equipment production | | | | |
| Share of capital, α_D | 0.30 | 0.30 | 0.30 | 0.30 |
| Fraction of R&D generating knowledge, ζ_D | 0.02 | 0.02 | 0.02 | 0.02 |
| Productivity of R&D, γ_D | 0.01 | 0.01 | 0.01 | 0.01 |
| Depreciation of R&D, δ_A | 0.025 | 0.025 | 0.025 | 0.025 |
| Depreciation of defence equipment δ_E | 0.025 | 0.025 | 0.025 | 0.025 |
| Defence services production | | | | |
| Share of equipment, α_{DD} | 0.50 | 0.50 | 0.50 | 0.50 |
| Defence equipment spending | | | | |
| Quasi-share of domestic defence equipment, ν_{GD} | 0.1483 | 0.0188 | 0.3276 | 0.0535 |
| Elast. of sub. btw. domestic and imp. def. equip., μ_{GD} | 1.50 | 1.50 | 1.50 | 1.50 |
| Quasi-share of bilateral def. equip. imports, ν_{MGD} | | | | |
| ...DE from... | - | 0.2111 | 0.6364 | 0.1543 |
| ...REA from... | 0.0807 | - | 0.8284 | 0.0909 |
| ...US from... | 0.0978 | 0.2090 | - | 0.6932 |
| ...RW from... | 0.0194 | 0.8690 | 0.1116 | - |
| Elast. of sub. btw. imported def. equip., μ_{MGD} | 1.50 | 1.50 | 1.50 | 1.50 |
| Dual-use capital | | | | |
| Productivity of dual-use capital, α_G | 0.01 | 0.01 | 0.01 | 0.01 |
| Depreciation of dual-use capital δ_G | 0.01 | 0.01 | 0.01 | 0.01 |
| Damage function for investment | | | | |
| Slope of ϕ_I in the steady state ψ_W | 3.57 | 3.57 | 3.35 | 3.38 |
| Sensitivity of ϕ_I to defence capabilities ψ_I | 2 | 2 | 2 | 2 |

Note: DE=Germany; REA=Rest of the euro area; US=United States; RW=Rest of world

We calibrate the delay between the payment for, and the delivery of, military equipment to be three years. We base this on estimates for German and UK military goods contained in Burilkov et al. (2025). We assume the speed of production is not vastly different across producers, and use the same numbers for all blocs in the model. In addition, we also calibrate the delay in the knowledge generation externality from defence sector R&D and its transmission to other sectors to be two years. We base this on the evidence in Antolin-Diaz and Surico (2025), where the productivity increase from R&D investment only begins to occur after two years.

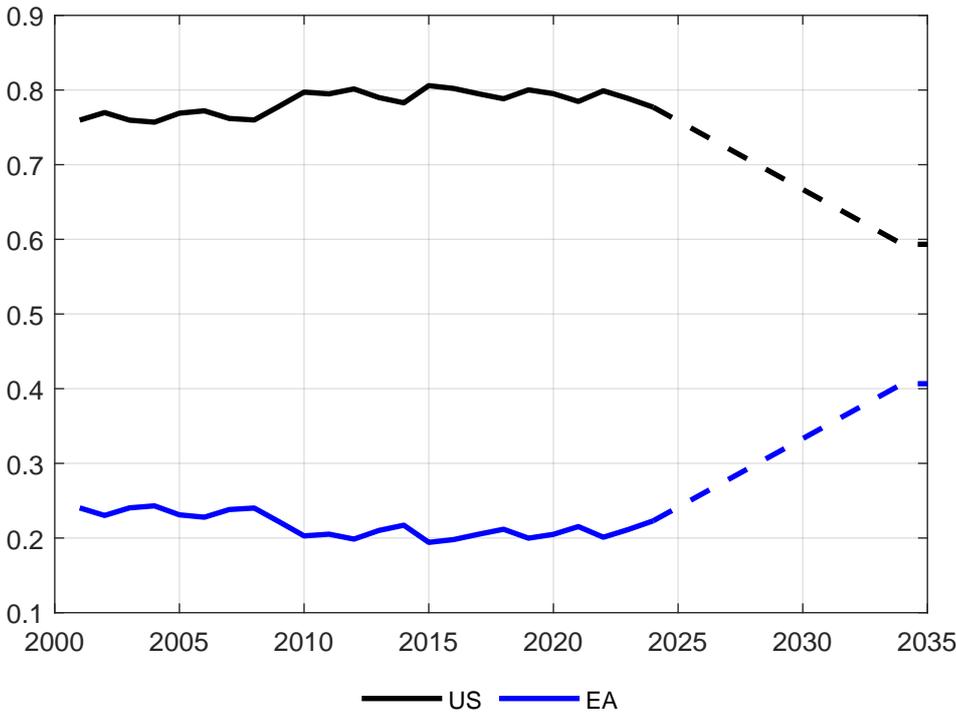
Dual-use goods are calibrated to account for the fact that these goods are typically long-lived (e.g., infrastructure) and set δ_G to 0.01, which implies a 25-year lifespan of such investments. Moreover, because they are by definition dual-use goods, they are less productive than typical public infrastructure goods, which is why we set α_G to 0.01, i.e.,

lower than would typically be the case (and below the lower end of the range in Leeper et al. (2010)).

4 Policy simulations

We utilise scenario analysis to examine the macroeconomic effects of changes in the extent and composition of European defence capabilities. We start with what we see as the impetus for the recent focus on this issue: a reduced contribution of the US to European deterrence.²⁷ Our baseline calibration sees the US account for almost 80% of this. We estimate that compliance with NATO targets, whereby military spending in the US and European NATO members will reach 5% of GDP per year by 2035, would reduce this share to around 60%. This is the black line in Figure 2, with our calculation of the share based on historical data represented by the full line and the projections based on NATO target compliance displayed using the dashed line.

FIGURE 2. Share of European deterrence provided



Source: Authors’ own calculations based on military expenditure data from SIPRI. Notes: Assumed share of US (black line) and EA (blue line) contributions to European deterrence, and the changes induced by compliance with the increased NATO military spending targets (dashed lines).

We initially assume that there is no change in EA military spending to offset this fall in defence capabilities. This allows us to explore the main mechanisms through which a

²⁷In our model framework, this is equivalent to the US contribution staying the same but the rest of the world bloc increasing their defence capabilities (i.e. an “arms race”). What matters is that the level of European deterrence has decreased, not the source of the change.

reduction in the US contribution to European deterrence affects the economy, without the additional complications resulting from simultaneous improvements in European capabilities.

We then assess how Europe can counteract this fall in the US contribution to deterrence by boosting military capabilities through an increase in (i) defence equipment, (ii) military personnel, and (iii) dual-use investments. We scale these increases such that they fully offset the reduced level of deterrence provided by the US (i.e. we return to a sufficient level of defence capabilities whereby security concerns no longer play a role in economic decision making). This transition occurs gradually, with almost all the change complete after ten years (i.e. broadly in line with NATO commitments). As we solve our model using perfect foresight, all agents in the model are fully aware of the paths these shocks will take.²⁸ We assume that countries finance this additional expenditure with debt issuance, with the fiscal rule ensuring that the debt-to-GDP ratio returns to the 60% target in the long run.²⁹

4.1 Decreasing US contribution to European deterrence

We first analyse the effect of a fall in deterrence, induced by a permanent reduction in the contribution of the US to European defence capabilities. We scale this such that the share of the US contribution in total European defence deterrent falls by 20 p.p. This amounts to approximately 40% reduction in the provision of defence deterrent of the US to Europe. We display the results in Figure 3, with the shock shown in the top-left panel.

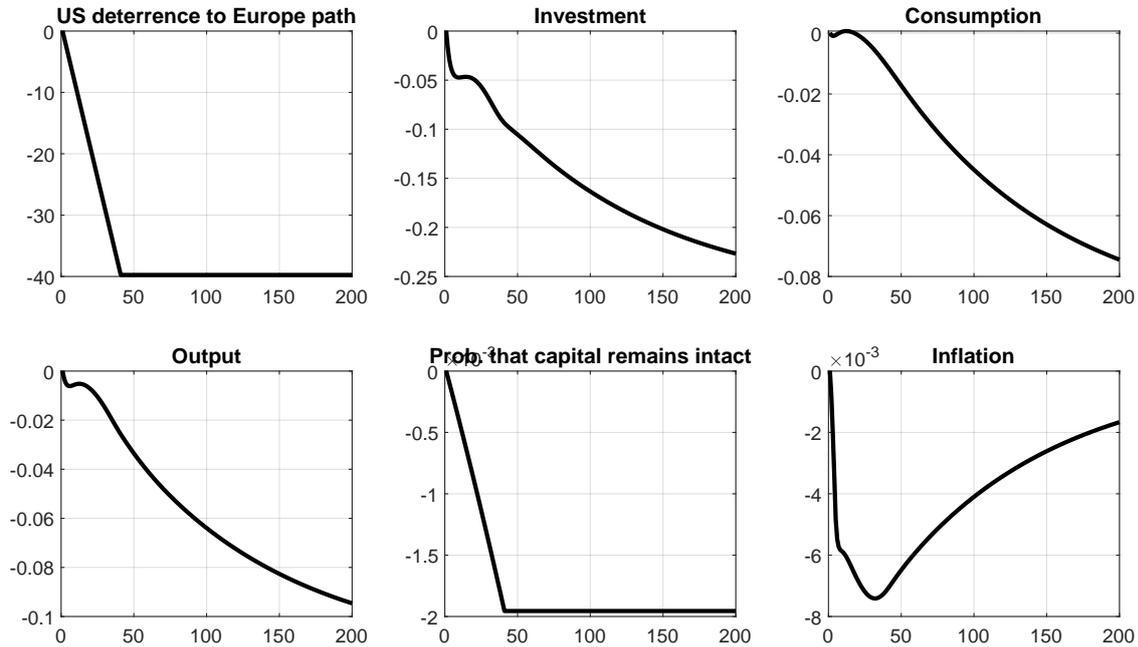
Without a response by European policymakers to actively boost their contribution to improved defence capabilities, security risk increases, which has a direct effect on the probability that the current and future capital remains intact. That probability decreases, which reads to a reduction in private investment. Reduction in private investment, and a (small) fraction of capital being impaired mean that there will be less capital available for production in the long run, and therefore less resources. This also results in a negative effect on consumption. Note that the changes in the probability are small, yet they still have sizeable effects. The main reason for strong effects is the very strong effect of lower investment and impaired capital on the available resources in the future.

In line with the reduction in aggregate demand, there is a (small) fall in inflation and interest rate (the latter not shown to save space).

²⁸The model is solved using a non-linear Newton-type algorithm in Dynare (see Adjemian et al. (2011) for details).

²⁹Our framework is sufficiently rich to allow us to analyse a range of different financing options. We leave this important issue for future research, as there are a wide range of potential options. Bolouri et al. (2025) find that individuals who value defence readiness tend to support deficit-neutral financing, whereas those less in favour prefer increased debt.

FIGURE 3. Permanent decrease in US contribution to European deterrence



Notes: Euro area responses to a permanent decrease in the share of the US contribution to European deterrence by 20 p.p.. The responses are percent deviations from initial steady state, except the probability and inflation (annualised), which are in percentage point deviations.

4.2 Increasing expenditure for defence equipment

We next examine the effects of a permanent increase in spending on defence equipment, equivalent to the NATO-agreed increase to 3.5% of GDP in Europe. European countries have historically spent about half of its defence budget on equipment and related expenditure (which includes here intermediate goods and materials). This amounts to an expenditure increase equivalent to 1.05 p.p. of ex-ante GDP from the current level. The remainder is allocated to spending on personnel, which we analyse below. We display the results in Figure 4 for real variables and in Figure 5 for nominal variables. In each figure we show the results for two cases, one where the R&D externality is active (full black lines) and one where the effect of the externality is negligible (red dashed lines).³⁰ This experiment is relevant because the literature shows some differences in this respect, as Antolin-Diaz and Surico (2025) find sizable long-run effects from spending on military R&D, while Federle et al. (2026) find no material TFP increase after a military spending increase.

The path of the shock is in the top-left panel of Figure 4. This is the change in defence equipment expenditure, expressed in percentage points of initial steady-state GDP, which increases gradually and reaches its new level after ten years. This is a direct government stimulus to output, which increases permanently by almost three

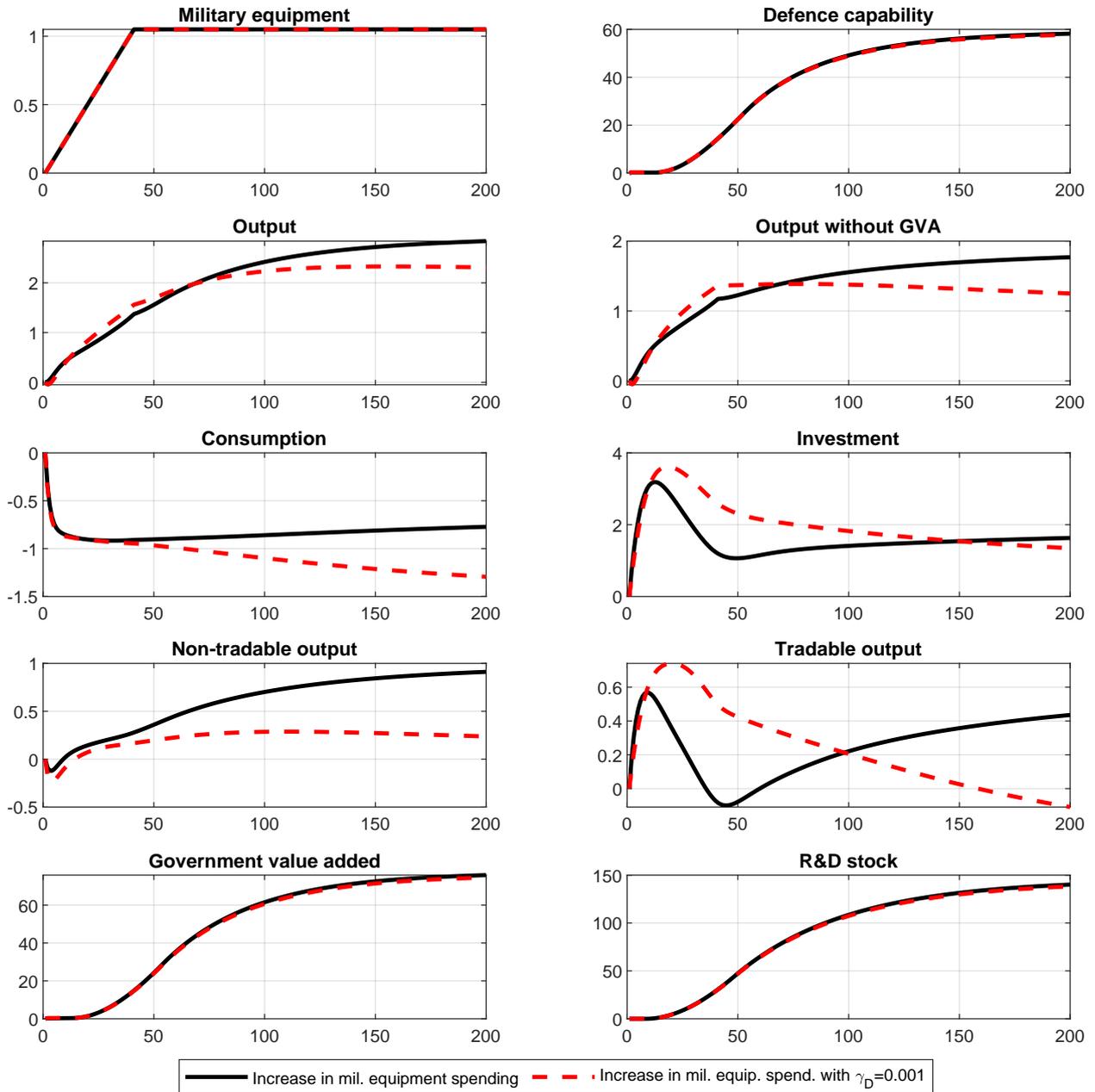
³⁰We achieve this by setting the parameter γ_D to a very low number, 0.001, at which level the stock of R&D has essentially no effect on production.

percentage points. About one third of this increase is due to the effect of R&D (the difference between the full black and dashed red lines in the top left panel), and an additional third is due to the contribution of government value added, coming from the depreciation of the (now larger) stock of military equipment. The latter matched the way this economic “activity” is captured in the national accounts. However, it is not value added that is available for private use. Because households know that debt-financed increases in defence spending imply future higher taxes, private consumption falls. This effect is stronger if the R&D externality is not present, because without it even less resources are available for private use.

Along with the increase in the size of the defence industry (following the path of the shock), the composition of output also sees a shift towards relatively more non-tradable production. Importantly, without the R&D externality, private sector production does not increase in the long run - in the final steady state, tradable private output falls by 0.2% and non-tradable private output increases by 0.1%). Therefore, the entire increase in output is due to defence industry production and the national accounts entries for government value added.

Defence capabilities are enhanced significantly, in line with importance of military equipment in the provision of deterrence. This boost comes with a delay due to the relatively lengthy built-in time to deliver military goods. Similarly, spillovers from the increase in defence industry R&D occurs with a delay (when this effect is present).

FIGURE 4. Permanent increase in defence equipment spending - real variables



Notes: Responses to a permanent increase in euro area defence equipment spending to NATO-agreed level, equivalent to an 1.05 p.p. of initial GDP increase. The responses are percent deviations from initial steady state, except defence equipment spending, which is in percentage point deviations from initial GDP.

We present the changes in nominal variables from this defence equipment spending increase in Figure 5. CPI inflation decreases slightly, but persistently, and the decrease is larger when there is no R&D channel. There are four reasons for this decrease. First, note that inflation is for consumption goods, i.e., it does not include the prices of military equipment. These are included in GDP deflator, which increases slightly and persistently.

Second, a significant proportion of consumption goods is imported, and prices fall on impact because of the appreciation of the euro exchange rate. This appreciation

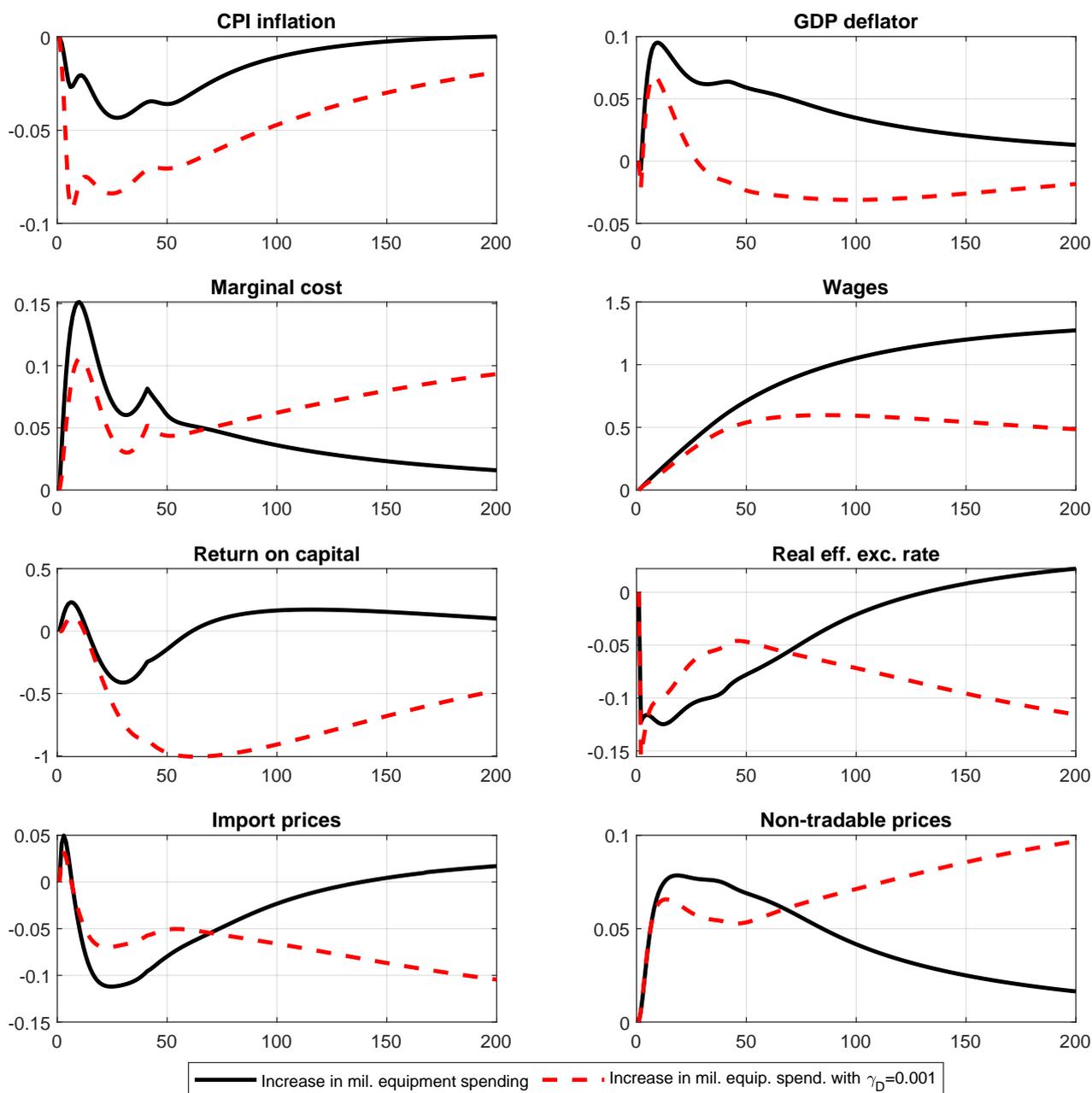
may be somewhat counterintuitive, because inflation falls and the interest rate in the euro area falls with it despite the GDP increase, so that the interest rate in the euro area is lower than in the US or the RW. However, note that this is a permanent shock and recall that consumption falls permanently. We cannot - as it would typically be the case in linearised models (see e.g. Galí (2020)) - ignore the change in the stochastic discount factor in the household optimality conditions with respect to domestic and foreign bonds.³¹ Because consumption falls, the stochastic discount factor increases, which by the uncovered interest parity implies the nominal exchange rate appreciation (and also real, as prices are sticky). This can happen even if the gap in nominal interest rates goes in the opposite direction, as long as the movement in the stochastic discount factor dominates the change in the interest rates.

Third, due to the local currency pricing, firms price their goods based on the situation on the export markets, and since a large share of consumption goods in Europe is imported, the fall of consumption in Europe causes a fall in demand for imported goods. This induces exporters from the US and RW to reduce their prices of exports to Europe in the medium run.

Fourth, marginal costs, which are the main driver of domestically-generated inflation, increase only mildly and only in the short and medium run. This happens despite the wage increase, and the reason is that the return on private capital falls, which offsets the increase in wages in the short to medium run. When the R&D channel is active, wages increase by more in the long run, but marginal costs fall nevertheless, because the stock of R&D acts like a productivity shock that drives a wedge between wages and marginal costs in the long run. When the R&D channel is not active (dashed red lines), wages do not increase as much, while the return on private capital falls more strongly, which largely offsets the effect of higher wages on marginal cost. These effects can clearly be seen in the path of non-tradable goods prices, which depend entirely on domestic factors. The initial increase in marginal costs is initially carried into non-tradable goods prices, but at a dampened scale (recall that firms set prices by looking at current and future marginal costs). In the short to medium run, it does not matter much whether the R&D channel is present or not. In the longer run, when the accumulated R&D has its largest effect on productivity, non-tradable goods prices fall. If this effect is not present, they increase, but by a tiny amount. However, in this case the movement of the real exchange rate dampens the transmission of the increase in domestic prices to inflation.

³¹The optimality condition for domestic bonds in Europe is $1 = R_t \beta \frac{\Lambda_{I,t+1}}{\Lambda_{I,t}} (\Pi_{C,t+1})^{-1}$ and for foreign bonds is $1 = R_t^{US} (1 - \Gamma_t^{B^*}) \beta \frac{\Lambda_{I,t+1}}{\Lambda_{I,t}} \frac{S_{t+1}^{H,US}}{S_t^{H,US}} (\Pi_{C,t+1})^{-1}$, where $\Lambda_{I,t}$ is the marginal utility of Ricardian households, R_t is the domestic (euro area) interest rate and R_t^{US} is the US interest rate, $\Pi_{C,t+1}$ is expected inflation, $S_t^{H,US}$ is the EUR/USD exchange rate, and $\Gamma_t^{B^*}$ is the adjustment cost to stabilise the net foreign assets. Combining these two equations yields $\beta \frac{\Lambda_{I,t+1}}{\Lambda_{I,t}} (\Pi_{C,t+1})^{-1} \left[R_t - R_t^{US} (1 - \Gamma_t^{B^*}) \frac{S_{t+1}^{H,US}}{S_t^{H,US}} \right] = 0$, which is the counterpart of equation 3 in Galí (2020) in our model. From this equation one can clearly see that for a permanent shock that changes the steady state the role of the movements in the stochastic discount factor for the exchange rate determination cannot be ignored.

FIGURE 5. Permanent increase in defence equipment spending - nominal variables



Notes: Responses to a permanent increase in defence equipment spending in the euro area to NATO-agreed level, equivalent to an 1.05 p.p. increase. The responses are percent deviations from initial steady state, except CPI inflation, which is in percentage point deviations from trend.

International spillovers from increased defence equipment spending are small, even with the R&D channel active, and we discuss these briefly in Appendix F.

4.3 Increasing military personnel

Defence equipment is not useful without (well-trained) military personnel to operate it. While the initial focus of the policy discussions largely emphasised expenditure targets, NATO members have been less explicit regarding the potential size of increases

in their armed forces. We next examine the macroeconomic implications of adjusting the number of military personnel. We scale this increase so that it accounts for the remainder of the increase of defence spending that is missing after increasing defence equipment spending to bring the overall level to 3.5% of GDP. After accounting for the wages paid to armed forces, this implies an increase in personnel by 38.2% in the REA and by 73.5% in Germany.³²

Governments can increase the size of their armed forces in two ways: by hiring a professional army, or through conscription of (segments of) the general population. There are different macroeconomic implications from these choices. Public-sector employment (i.e. armed forces composed of professional recruits) affects GDP via expenditure on employees' wages, which increases government value added. However, conscription generally involves below-market payment, or in some cases no payment at all, for labour services provided. Currently, almost all militaries in Europe are professional, but a move to conscription is nevertheless a plausible option. We investigate this by running two simulations. The benchmark simulation, shown in full black lines in Figures 6 and 7, assumes that the military personnel is paid competitive wage.³³ The alternative simulation, shown in dashed red lines, assumes that countries move to partial conscription - in particular, that the increase in military personnel is achieved by simultaneously moving to 80% of conscription gradually over ten years (we assume that the remaining 20% of personnel is hired as professional army).³⁴

Figure 6 shows the effect of military personnel increase on real-economy variables. The increase in military personnel is significant, amounting to somewhat over 40% increase on average in the euro area. This increase crowds-out labour from the private sector, which happens despite the decrease in consumption which, everything else equal, would increase labour supply. There is a mild increase in output, but this is entirely due to the government value added, as output without this component falls. In the private sector, both tradable and non-tradable output decline. Investment initially increases to substitute for the fall in labour, but investment falls in the long run.

Because government value added critically depends on wage expenditure for the military personnel, the case with conscription shown in red dashed lines has negative effects even on output that includes government value added. The latter falls significantly in the case with (partial) conscription, because the government saves on the (gross) wage bill of the military personnel. The consequence of this is that it does not have to raise as much taxes in the future, which households internalise by reducing consumption by less when there is conscription. This happens despite the fact that the average military personnel receives much lower wages, as 75% of households in the model are Ricardian, so they can smooth their consumption using assets and income (and they know that the reduction in wage income will be compensated by the reduction in taxes).

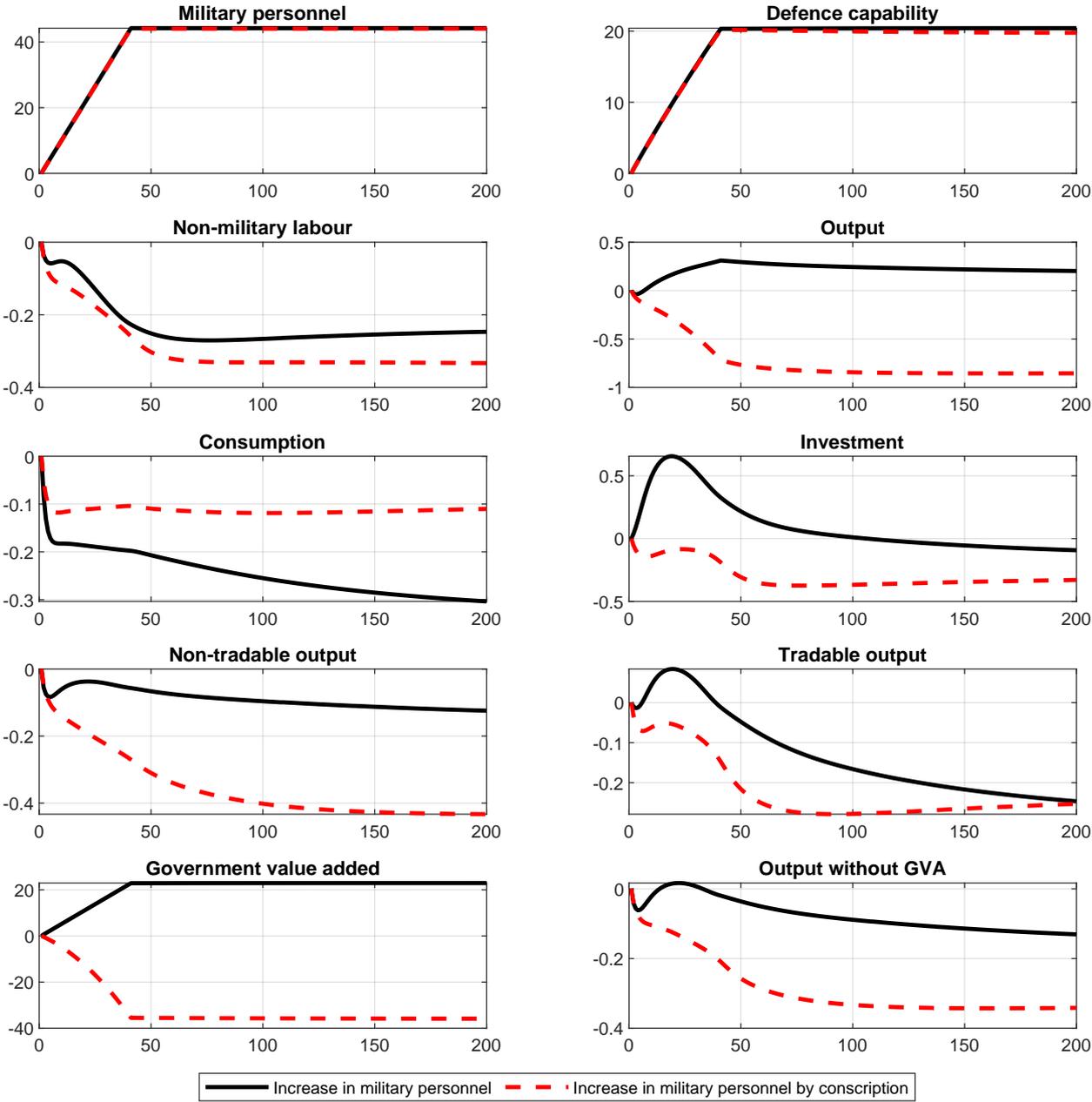
³²Army sizes as a proportion of the total population differ significantly across Europe, and so does the split between equipment and personnel spending, with German military personnel accounting for about 0.5% of population and other countries closer to 1%.

³³Because we simulate a permanent shock, wages change, and we assume that military wages follow the long-run movement in private wages.

³⁴This is equivalent to assuming that all additional personnel is hired by conscription, but is paid 20% subsistence payment.

An increase in military personnel implies a boost to defence capability and therefore deterrence.

FIGURE 6. Permanent increase in personnel - real variables



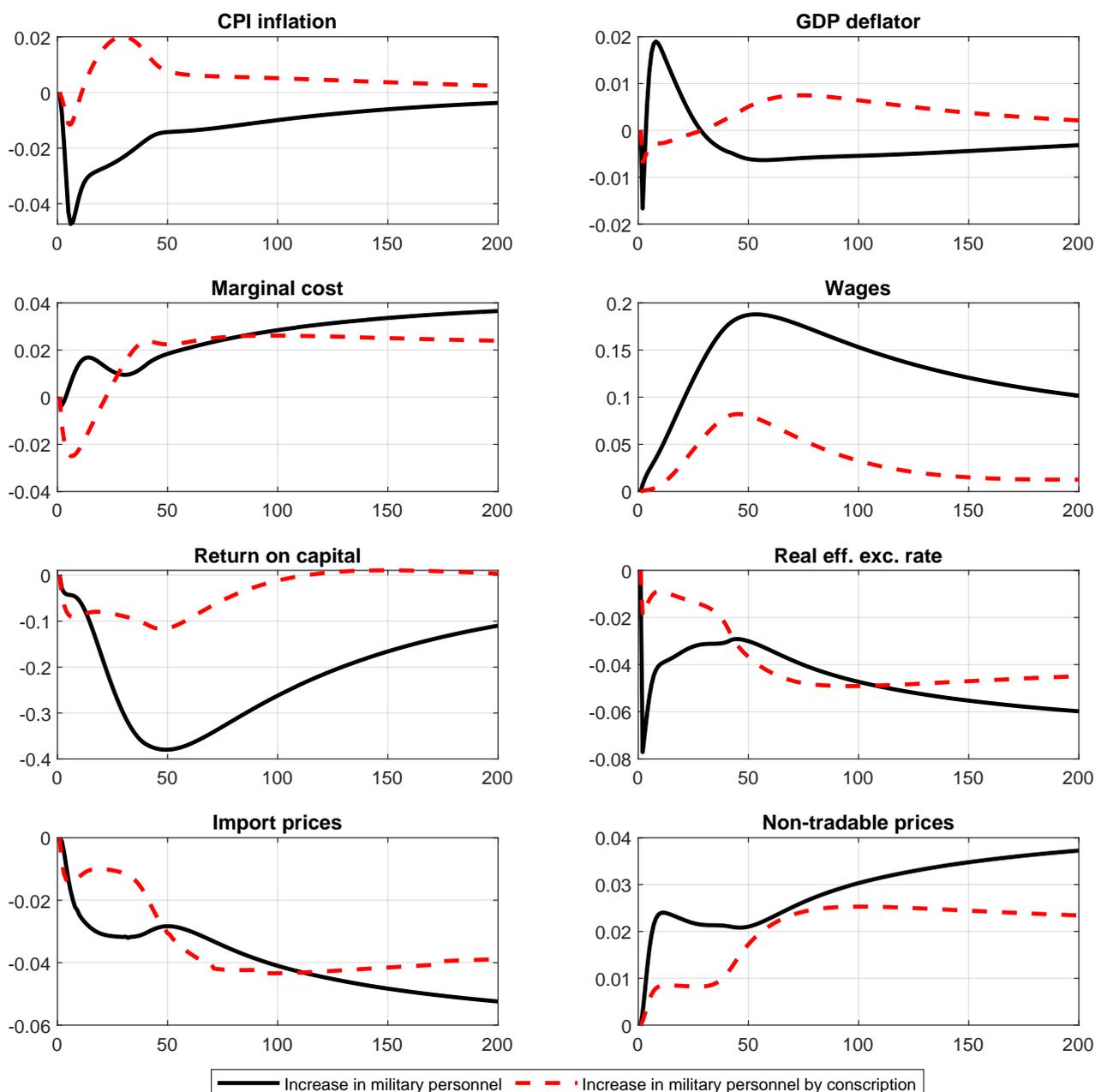
Notes: Responses to a permanent increase in military personnel in the euro area to NATO-agreed level, equivalent to an 38.2% increase in the REA and 73.5% increase in Germany. The responses are percent deviations from initial steady state.

Figure 7 shows the effects of military personnel increase on nominal variables. Wages increase because the demand for labour increases by more than supply of labour. There is an accompanying decrease in the return on capital, which alleviates the effect of wage increase on marginal costs and inflation. Inflation falls because of the euro appreciation, which, together with the lower domestic demand, is having a negative

effects on import prices. Domestic prices, as proxied by non-tradable goods prices, increase mildly.

The effects on nominal variables differ depending whether there is conscription or not. With conscription, CPI inflation increases mildly. This is explained by a lower (and slower) exchange rate appreciation compared to the case without conscription. Marginal costs do not differ much between the two cases, but their composition does. In the case with conscription, wages increase by much less than in the case without, and the return on capital falls by much less than in the case without conscription. The reason behind the lower increase in wages with conscription is the lower fall in consumption, which means that labour supply increases by less than in the case without conscription. But less labour supply also implies that investment in capital becomes less attractive and price of investment goods (which determines the return on capital) falls by less than in the case without conscription. The resulting decline in investment further reduces aggregate demand and output in the short run.

FIGURE 7. Permanent increase in personnel - nominal variables



Notes: Responses to a permanent increase in military personnel in the euro area to NATO-agreed level, equivalent to an 38.2% increase in the REA and 73.5% increase in Germany. The responses are percent deviations from initial steady state, except CPI inflation, which is in percentage point deviations from trend.

4.4 Increasing dual-use investment

Investing in technology and infrastructure that has both a civilian and a military use is a key component of the updated NATO expenditure targets. We simulate an increase in dual-use investment increase that is equivalent to the NATO-agreed targets, which amounts to a permanent increase in dual-use investment of 0.9 p.p. of ex-ante GDP in the euro area. The results are shown in Figures 8 and 9. We show two cases, the

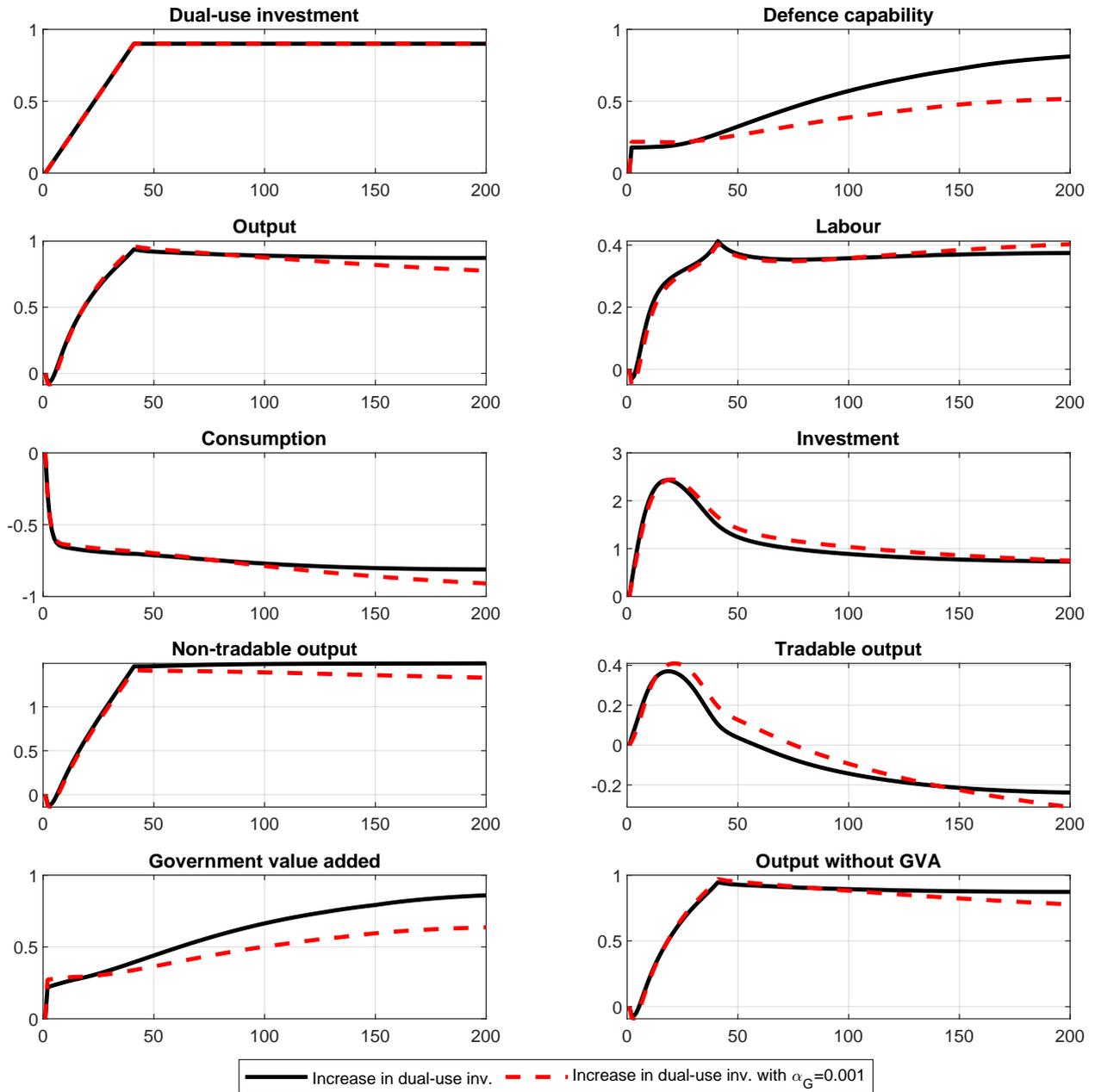
benchmark case with productive dual-use investment (full black line) and an alternative case, where dual-use investment is not productive (or its productivity is negligible), so that it resembles a standard government consumption spending shock typically analysed in the literature.

Figure 8 shows the results for the variables related to the real economy. The increase in dual-use investment leads to an increase in economic activity for two reasons. First, it increases demand for investment goods by the government, and second, if public capital stock has a productivity externality on private sectors (which happens when α_G is larger), it acts as a productivity shock that can increase aggregate resources. It turns out that the increase in output is about the same as the increase in government spending on investment, regardless of whether this is measured by including or excluding government value added, as this is relatively small compared to other components of output.

An increase in dual-use investment crowds-out private consumption, as households expect higher tax burden in the future to finance government investment. Because households' consumption falls, they supply more labour, in order to prevent an even stronger fall in consumption. In order to keep the capital-labour ratio, firms also demand more capital, leading to an increase in investment. Output composition changes in favour of non-tradable goods because government investment is fully biased towards non-tradables. In the longer run this takes resources from tradable sector, whose output declines in the long run. Because dual-use investment plays a role in defence, there is a small increase in defence capability, but this increase is very small compared to the increases seen when government spending is focused on military equipment or personnel.

There is relatively little role for the productivity of dual-use investment, i.e., black and dashed red lines lie relatively close together. If dual-use investment has little or no externalities in terms of productivity, the long run the increase in output is smaller, crowding-out of consumption is stronger, the increase in non-tradable output is smaller and the fall in tradable output is stronger.

FIGURE 8. Permanent increase in dual-use investment spending - real variables

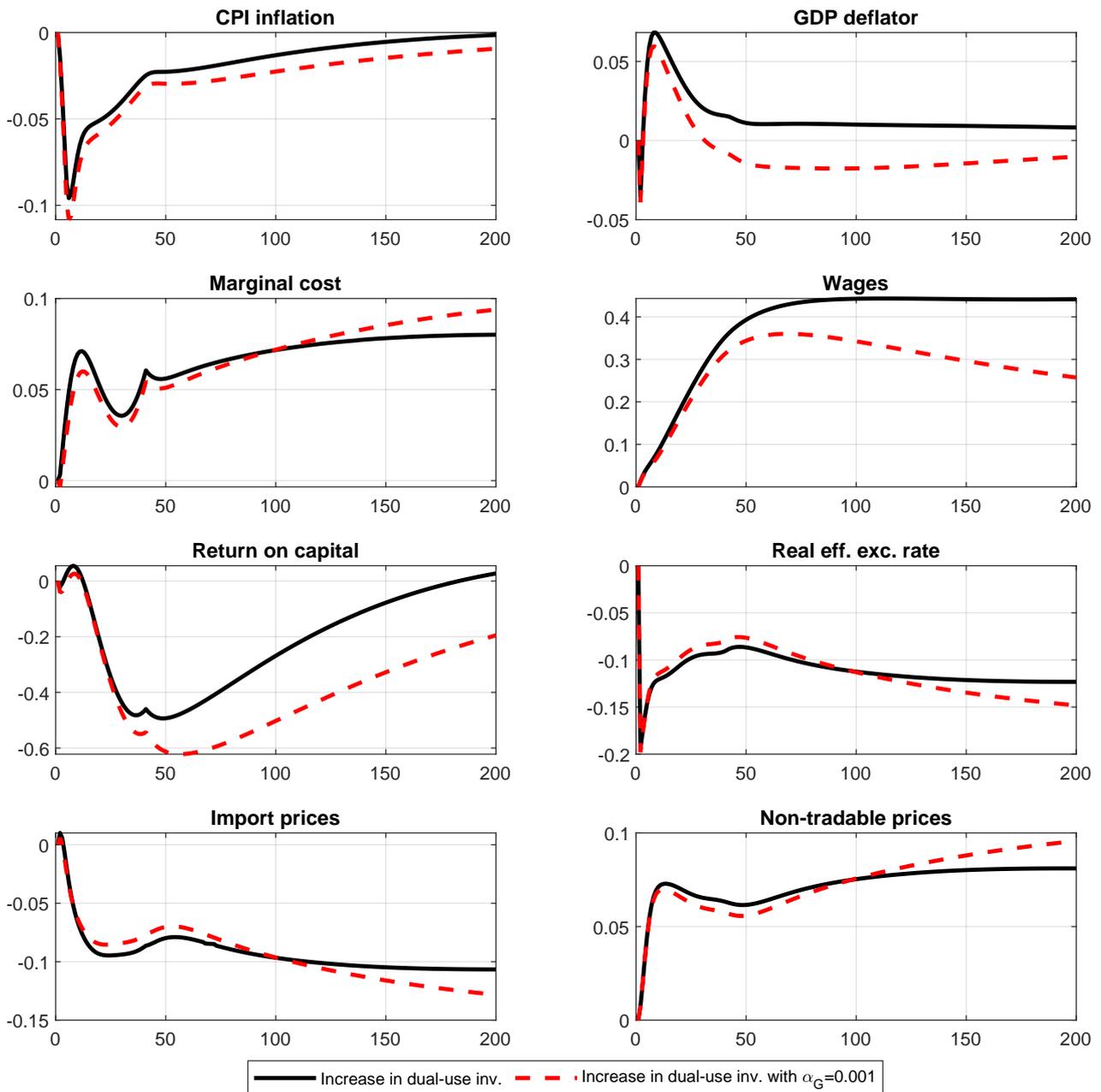


Notes: Responses to a permanent increase in dual-use investment spending in the euro area to NATO-agreed level, equivalent to a 0.9 p.p. increase. The responses are percent deviations from initial steady state, except dual-use investment spending, which is in percentage point deviations from initial GDP.

Figure 9 shows the effects of dual-use investment increase on nominal variables. As in previous simulations, there is a fall in CPI inflation, caused by the euro appreciation and a reduction in demand for imports that lowers import prices in the short and long run. GDP deflator increases in the short run, but the change is small. Marginal costs of firms increase mildly, but the increase is not enough to offset the fall in import prices. Similarly as for the R&D effects in the case of government spending on equipment, higher productivity of dual-use investment allows for a stronger increase in wages in the longer

run without the stronger increase in marginal costs. When this channel of productivity of dual-use investment is not operational, the stronger decline in the return on capital and a lower increase in wages jointly prevent a strong increase in marginal costs and therefore domestic inflation.

FIGURE 9. Permanent increase in dual-use investment spending - nominal variables



Notes: Responses to a permanent increase in dual-use investment spending in the euro area to NATO-agreed level, equivalent to a 0.9 p.p. increase. The responses are percent deviations from initial steady state, except CPI inflation, which is in percentage point deviations from trend.

4.5 The entire policy package

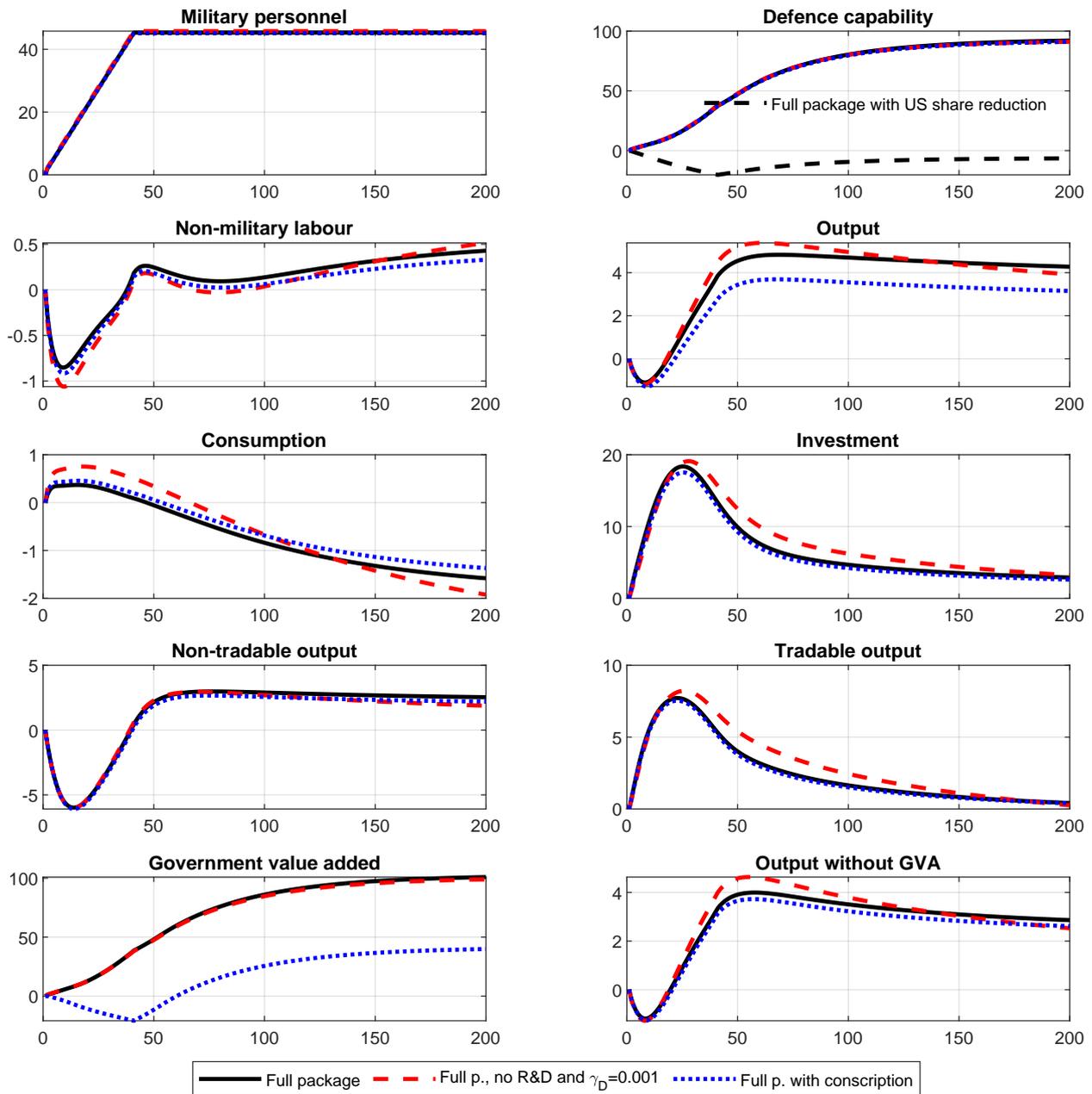
The agreement by the NATO on defence spending stipulates that *all* measures discussed above in isolation will be implemented jointly. This section analyses the entire policy package agreed, i.e., the increase in equipment spending, the increase in military personnel and in dual-use investment, along with the assumption that the US contribution to the European defence will shrink (as discussed in Section 4.1). As when examining these shocks individually, we will also here examine the sensitivity of results to some of the key assumptions regarding R&D, productivity of public investment, and conscription.

The results of the full policy package implementation are shown in Figures 10 and 11. The full black line shows the benchmark case that assumes some productivity spillovers from R&D and from productive public investment. The dashed red line shows the alternative, where the contribution of R&D and productivity of public investment are switched off. Finally, the dotted blue line shows the case that is identical to the benchmark, but with the transition to (partial) conscription instead of the fully professional army.

Figure 10 shows the effect of the full policy package on real variables. In all cases there is a small fall in output in the short run, followed by a significant increase. Private consumption increases initially due to the monetary stimulus in response to lower inflation, but decreases materially in the longer run. Labour first decreases, but increases mildly in the long run. Government value added contributes almost half of the increase in output in the long run, while private output reallocates towards non-tradable output in the long run. The latter is partly due to the full bias of dual-use investment towards non-tradable output. There is a significant increase in private investment over the short and medium run, driven by the increased demand for capital for production, which comes from the shortage of the availability of labour, especially in the short run. European defence capabilities almost double, but if the US retracts part of its defence capability provisions (recall that we assumed initially that this provision will decrease by 20 percentage points of its initial contribution), the NATO-agreed increases in defence spending in Europe will just suffice to maintain approximately unchanged level of defence capabilities in the long run.³⁵

³⁵This is why we assumed - admittedly somewhat arbitrary - that the US will decrease its defence provision to Europe by 20 p.p. of its initial contribution.

FIGURE 10. Full policy package - real variables

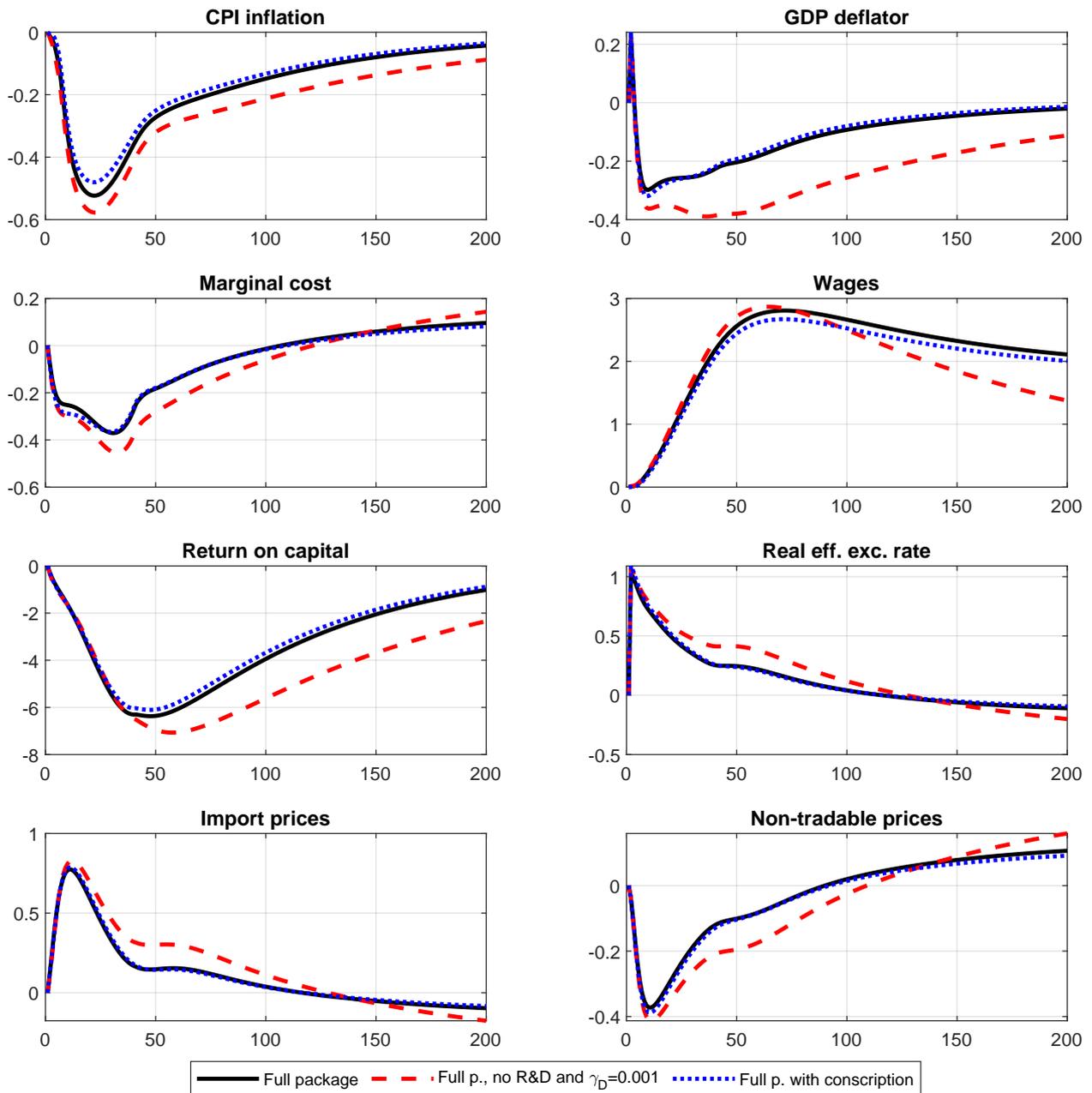


Notes: Responses to a permanent increase in military equipment and dual-use investment spending, and the increase in military personnel in the euro area to NATO-agreed level. The responses are percent deviations from initial steady state.

Figure 11 shows the responses of nominal variables. Both CPI inflation and GDP deflator fall persistently due to the decline in marginal costs, which is driven by the decline in the return on capital, driven in turn by the decline in the price of investment goods. While wages increase due to the shortage of labour, this is not sufficient to offset the decrease in the return on capital, which results in a persistent decrease in marginal costs and therefore prices (this effect is most visible in non-tradable goods prices, which depend on domestic conditions). When the full policy package is implemented jointly, the real effective exchange rate depreciates, which is caused by monetary policy easing

in Europe, driven by the fall in inflation. The decrease in the interest rate in this case is strong enough to even mildly increase consumption on impact, so that the stochastic discount factor falls initially, which now works in the same direction as the interest rate differential and leads to euro depreciation, unlike in the cases where we considered defence spending components in isolation. The depreciation in the euro increases import prices, but the increase is not sufficiently strong to offset the decrease in non-tradable goods prices.

FIGURE 11. Full policy package - nominal variables



Notes: Responses to a permanent increase in military equipment and dual-use investment spending, and the increase in military personnel in the euro area to NATO-agreed level. The responses are percent deviations from initial steady state, except CPI inflation, which is in percentage point deviations from trend.

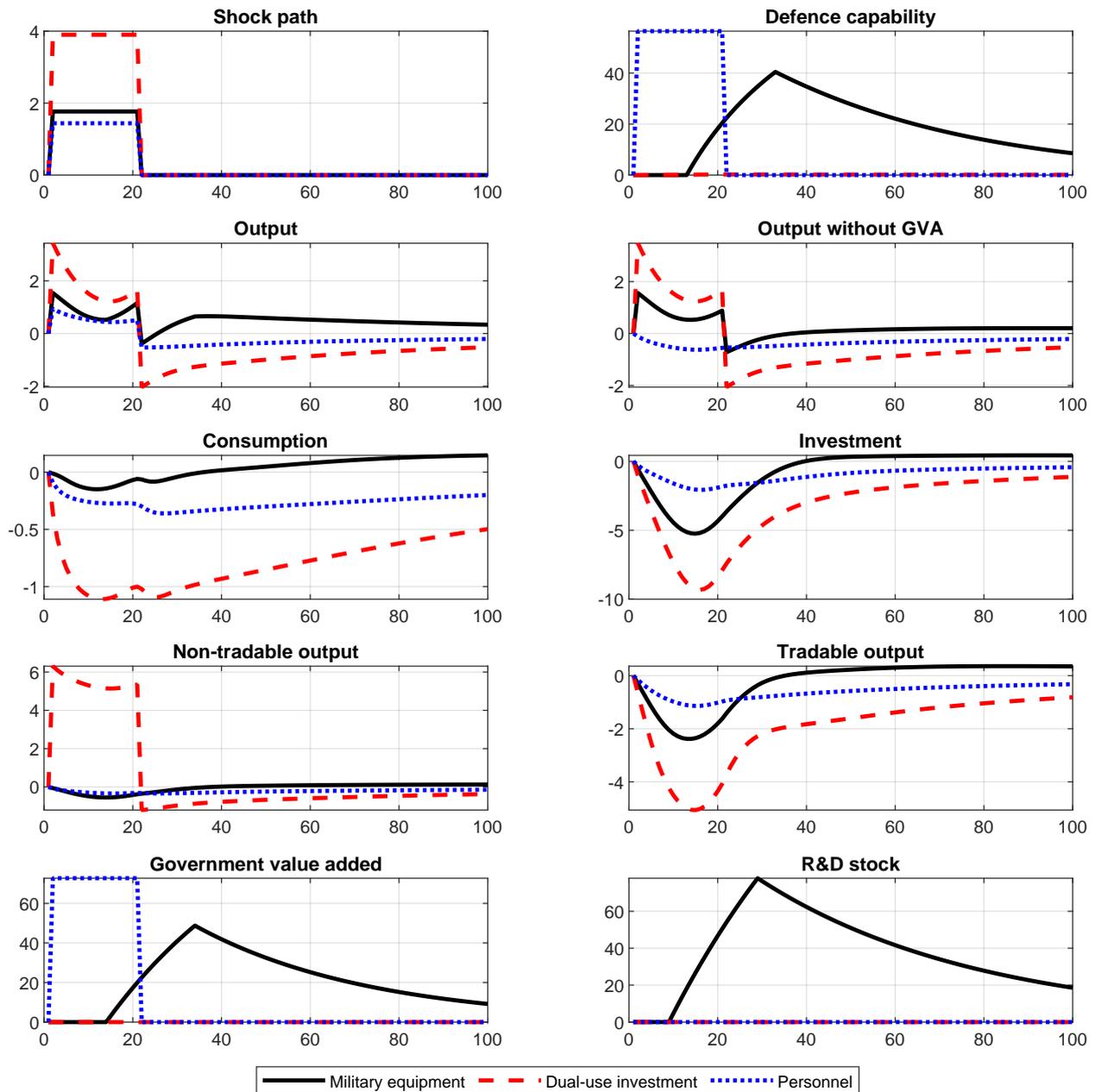
Variations in R&D expenditure and in the productivity of dual-use investment are to some extent important, but do not modify the overall results materially. Overall, we see a material restructuring of the economy from private-use production to government-use production and government value added. The overall result is not welfare improving in the sense that households consume less and work more in the longer run.

5 Temporary increase in defence expenditure

So far we analysed a permanent shift to an elevated level of defence spending, i.e., a transition to a new steady state. However, it may happen that increased defence spending will at some point be reversed, as it has negative effects on private consumption (and, more broadly, on private welfare, since typically we see both a fall in private consumption and an increase in labour). To address this possibility - and, more importantly, to highlight the channels of transmission - this section investigates a 5-year increase in defence spending for the three categories considered in the main body of the paper. Specifically, there is an immediate increase of each category to the NATO-agreed level, which lasts 5 years and then returns to the current level. The results are shown in Figure 12 for real variables and in Figure 13 for nominal variables.

The responses of real variables in Figure 12 are qualitatively mostly in line with the observed responses to permanent shocks, at least in the short run: Output increases and the increase is in part due to the government value added (which is fully the case when there is a personnel increase). There is crowding-out of private consumption that is often long-lasting (consumption responses are quite persistent due to habit formation). Output composition changes towards less tradable and more non-tradable output (especially for dual-use investment, which has full home bias).

FIGURE 12. Temporary shocks - real variables



Notes: Responses to a temporary shock (5-year increase) in military equipment spending, dual-use investment, and military personnel, in the euro area to NATO-agreed level. The responses are percent deviations from initial steady state. The path of the military personnel has been divided by 100.

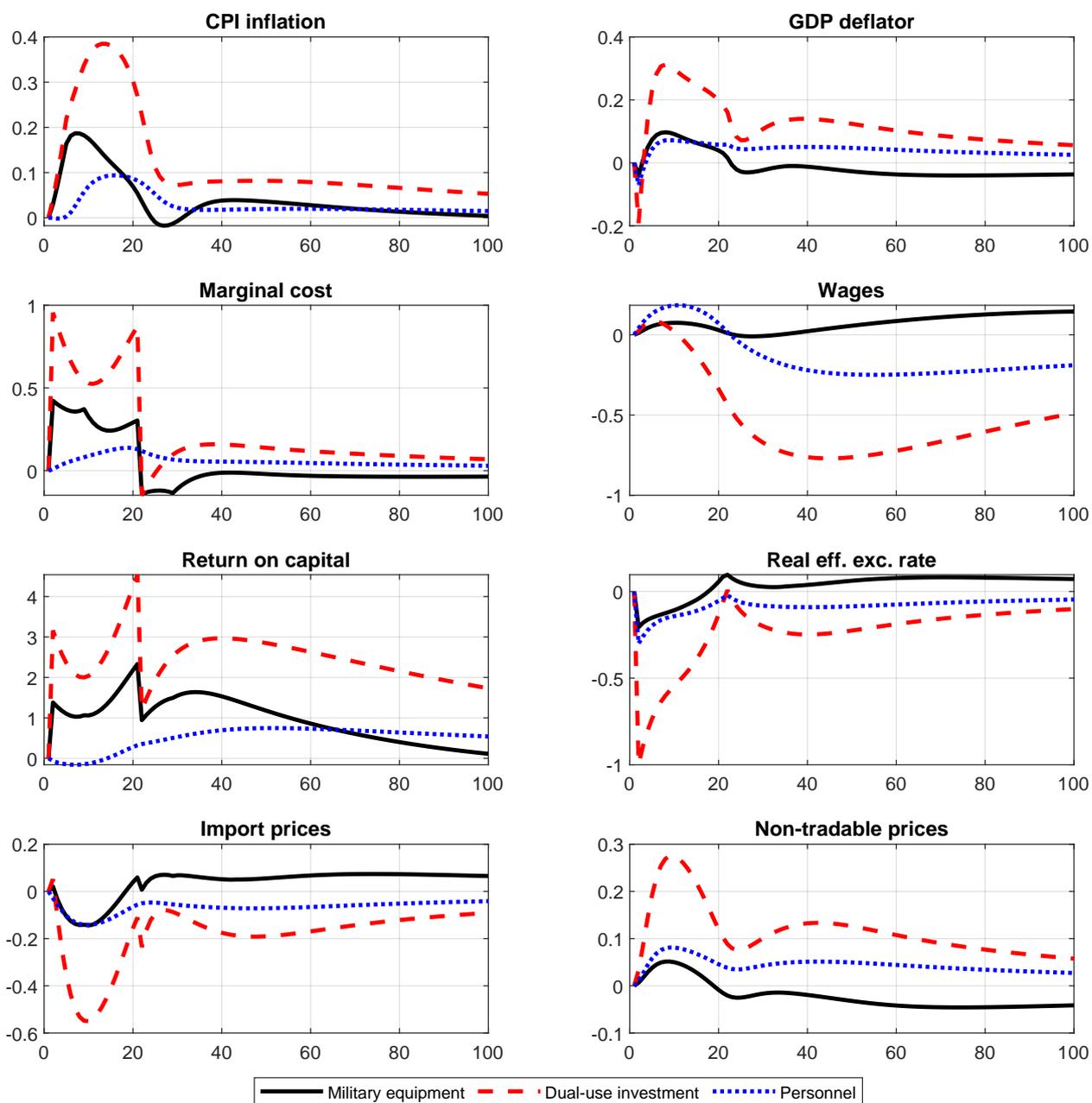
The main difference compared to permanent shocks comes from the response of CPI inflation, shown in the top-left panel of Figure 13. Unlike after a permanent shock, inflation increases after a temporary shock, and the increase is persistent (which is partly due to indexation). Real exchange rate still appreciates on impact, but then quickly starts reverting to its initial level or even depreciates slightly, rather than staying permanently at an appreciated level. In contrast to the permanent shock, marginal costs now increase materially over the short run and this dominates the effect of the real exchange rate

appreciation and falling import prices. The increase in marginal costs is now caused mostly by the strong and persistent increase in the return on capital and partly by the increase in wages in the short run.

To better understand the differences between a permanent and a temporary shock it is useful to look at Figure 14, which contrasts the effect of permanent and of temporary shock for some of the main variables that determine the exchange rate and return on capital (to avoid clutter, we show this only for the case of an increase in military equipment expenditure).³⁶ First note that in the case of the temporary shock, the exchange rate appreciation in the euro area is caused by the increase in the interest rate (rather than by the movement in the stochastic discount factor (SDF), as is the case for permanent shock). There is also a material difference in the responses of the return of capital, which increases strongly in the case of a temporary shock, as rising interest rates induce first a fall, and then the increasing path of Tobin's q and the price of investment goods (in the permanent shock case, the paths of these variables are falling after the initial increase).

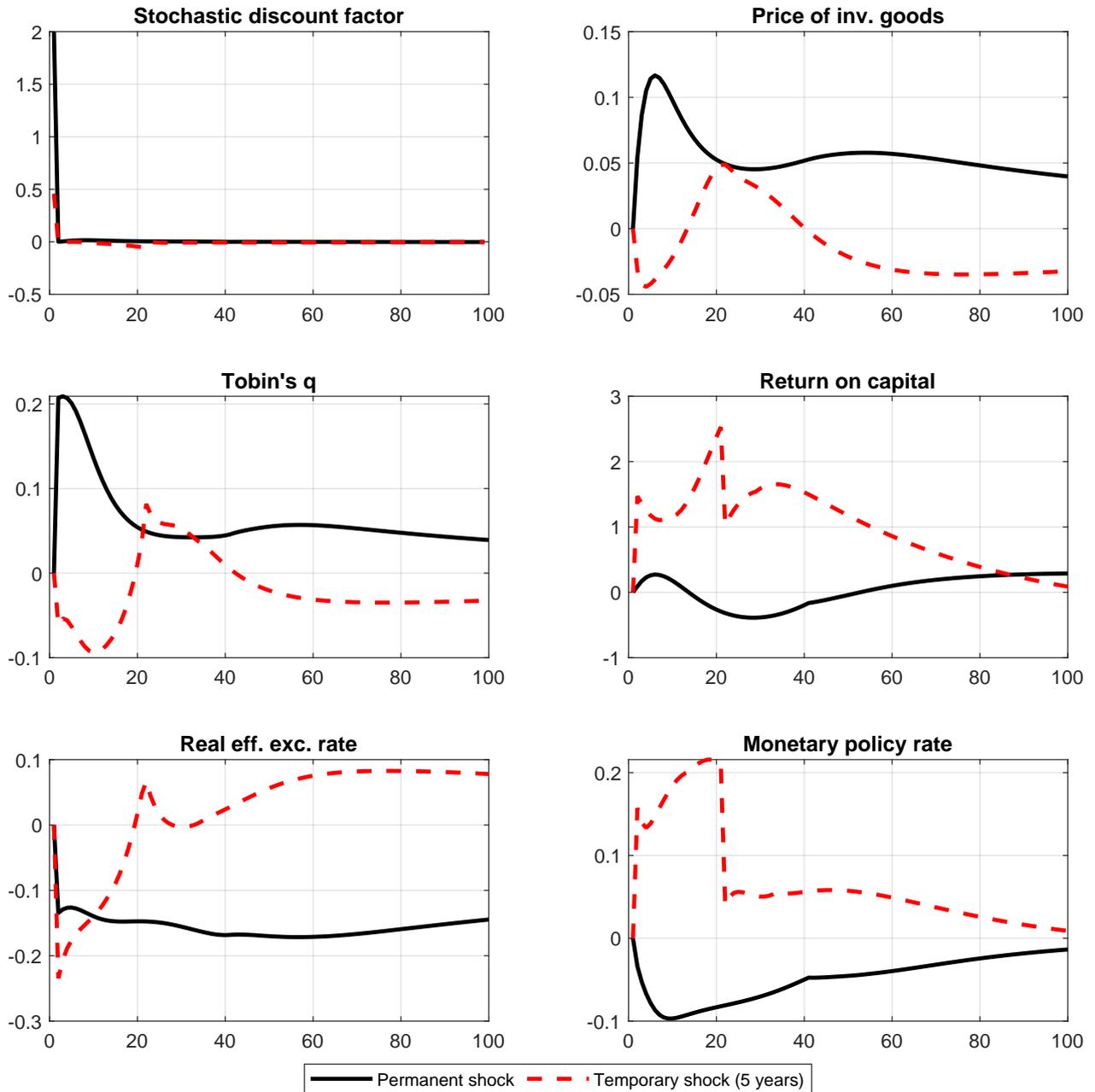
³⁶The path of consumption differs markedly between permanent and temporary shocks. In the case of the permanent shock, consumption typically declines initially and keeps declining to the lower level, while in the case of a temporary shock it declines initially and then keeps rising to the initial level.

FIGURE 13. Temporary shocks - nominal variables



Notes: Responses to a temporary shock (5-year increase) in military equipment spending, dual-use investment, and military personnel, in the euro area to NATO-agreed level. The responses are percent deviations from initial steady state, except CPI inflation, which is in percentage point deviations from trend.

FIGURE 14. Permanent vs. temporary increase in military equipment spending



Notes: Responses to a temporary shock (5-year increase) in military equipment spending, dual-use investment, and military personnel, in the euro area to NATO-agreed level. The responses are percent deviations from initial steady state. The path of the military personnel has been divided by 100.

6 Concluding remarks

For decades, European firms and households did not have to factor external security risks into their decision making. This may change in the coming years due to combination of a rise in these threats and a reduction in the US contribution to European deterrence. In view of this, the NATO members have agreed on a number of measures to improve

the defence and security situation. These measures involve a number of government spending targets, which are not necessarily comparable with the government spending that is used in standard macroeconomic models. In this paper we develop a modelling framework that allows us to explore the effects of different policy measures agreed by the NATO members and their economic implications.

We show how a decrease in deterrence, induced by a reduction in the US contribution to European defence capabilities, can lead to a drop in all forms of economic activity. This is through the negative effect of increased security risk on private investment and consumption decisions. In contrast, enhancing European defence capabilities boosts aggregate output (GDP). This is through increased defence industry production, government value added due to higher military employment and increased depreciation of military equipment (both of which count as GDP in the National Accounts). However, in all cases resources available for private use decline because labour and capital used for military purposes cannot be utilised for other (private) purposes. The negative effects on the private economy can be somewhat alleviated if spending on military equipment can generate technological spillovers to the rest of the economy and if dual-use investment is productive when used in private sectors.

Our analysis is preliminary, and focuses on illustrating the main transmission channels from our framework. Future work could use our rich modelling structure to delve deeper into the various issues facing policymakers. For example, we could explore the macroeconomic implications of how governments will finance this additional expenditure. The large debt stock of many European countries means that tax increases and/or expenditure cuts may be necessary. We could examine the role of the US in developing European defence capabilities and the trade-offs inherent in lesser or greater coordination. Or the attractiveness of the wage conscripts, or professional recruits, receive.

Our framework can also incorporate the inclusion of an additional small open economy with minimal impact on euro area aggregates (i.e. most European countries). This would allow us to explore the spillovers from coordinated and differential national policies.

References

- Acemoglu, D., 2002. Directed technical change. *The review of economic studies* 69, 781–809.
- Adema, J., Poutvaara, P., Schlepper, M., Taghiyev, T., Wochner, T., 2024. Volkswirtschaftliche kosten einer wiedereinführung der wehrpflicht oder eines sozialen pflichtjahres. *ifo Forschungsberichte*.
- Adjemian, S., Bastani, H., Juillard, M., Mihoubi, F., Perendia, G., Ratto, M., Villemot, S., 2011. *Dynare: Reference Manual, Version 4*.
- Antolin-Diaz, J., Surico, P., 2025. The long-run effects of government spending. *American Economic Review* 115, 2376–2413.
- Antonova, A., Luetticke, R., Muller, G.J., 2025. The Military Multiplier. Technical Report. CESifo Working Paper.
- Anzoategui, D., Comin, D., Gertler, M., Martinez, J., 2019. Endogenous technology adoption and r&d as sources of business cycle persistence. *American Economic Journal: Macroeconomics* 11, 67–110.
- Benigno, G., Fornaro, L., 2018. Stagnation traps. *The Review of Economic Studies* 85, 1425–1470.
- Bolouri, A.A., Lohse, T., Qari, S., 2025. Interdependent preferences for financing and providing public goods—the case of national defense. *Kyklos*.
- Broner, F., Martin, A., Meyer, J., Trebesch, C., 2025. Hegemonic globalization.
- Brzoza-Brzezina, M., Jacquinet, P., Kolasa, M., 2014. Can we prevent boom-bust cycles during euro area accession? *Open Economies Review* 25, 35–69.
- Burilkov, A., Bushnell, K., Mejino-López, J., Morgan, T., Wolf, G.B., 2025. Kiel Report 2025: Fit for war by 2030? European rearmament efforts vis-à-vis Russia. Technical Report. Kiel Institute for the World Economy.
- Caldara, D., Iacoviello, M., 2022. Measuring geopolitical risk. *American economic review* 112, 1194–1225.
- Calvo, G.A., 1983. Staggered prices in a utility-maximizing framework. *Journal of monetary Economics* 12, 383–398.
- Christoffel, K.P., Coenen, G., Warne, A., 2008. The new area-wide model of the euro area: a micro-founded open-economy model for forecasting and policy analysis.
- Clancy, D., Jacquinet, P., Lozej, M., 2016. Government expenditure composition and fiscal policy spillovers in small open economies within a monetary union. *Journal of Macroeconomics* 48, 305–326.
- Clancy, D., Merola, R., 2017. Countercyclical capital rules for small open economies. *Journal of Macroeconomics* 54, 332–351.

- Clancy, D., Smith, D., Valenta, V., 2024. The macroeconomic effects of global supply chain reorientation. *International Journal of Central Banking* .
- Clayton, C., Maggiori, M., Schreger, J., 2023. A framework for geoeconomics. Technical Report. National Bureau of Economic Research.
- Coenen, G., Lozej, M., Priftis, R., 2024. Macroeconomic effects of carbon transition policies: an assessment based on the ecb's new area-wide model with a disaggregated energy sector. *European Economic Review* 167, 104798.
- Cox, L., Müller, G.J., Pasten, E., Schoenle, R., Weber, M., 2024. Big g. *Journal of Political Economy* 132, 3260–3297.
- Draghi, M., 2024. The future of European competitiveness – A competitiveness strategy for Europe. Report. European Commission. URL: https://commission.europa.eu/document/download/97e481fd-2dc3-412d-be4c-f152a8232961_en?filename=The%20future%20of%20European%20competitiveness%20_%20A%20competitiveness%20strategy%20for%20Europe.pdf.
- EC, 2025. The cost of EU Member States' proximity to the war. Technical Report. European Commission.
- Enders, T., zu Fürstenberg, J., Obermann, R., Schularick, M., 2025. Advanced technology as europe's strategic imperative. *The Economic Consequences of the Second Trump Administration: A Preliminary Assessment* .
- Erceg, C.J., Lindé, J., Trabandt, M., 2024. Monetary policy and inflation scares .
- Faruqee, H., Laxton, D., Muir, D., Pesenti, P., 2008. Would protectionism defuse global imbalances and spur economic activity? a scenario analysis. *Journal of Economic Dynamics and Control* 32, 2651–2689.
- Federle, J., Meier, A., Müller, G.J., Mutschler, W., Schularick, M., 2026. The price of war. *American Economic Review* 116, 791–827.
- Federle, J., Rohner, D., Schularick, M., 2024. Who wins wars? Available at SSRN 5093393 .
- Fieldhouse, A., Mertens, K., 2023. The returns to government r&d: Evidence from us appropriations shocks .
- Galí, J., 2020. Uncovered interest parity, forward guidance and the exchange rate. *Journal of Money, Credit and Banking* 52, 465–496.
- Golosov, M., Hassler, J., Krusell, P., Tsyvinski, A., 2014. Optimal taxes on fossil fuel in general equilibrium. *Econometrica* 82, 41–88.
- Gomes, S., Jacquinot, P., Pisani, M., 2012. The eagle. a model for policy analysis of macroeconomic interdependence in the euro area. *Economic Modelling* 29, 1686–1714.
- Hartley, K., Solomon, B., 2015. Measuring defense output: An economics perspective, in: *Military cost-benefit analysis*. Routledge, pp. 70–107.

- Hassler, J., Krusell, P., Olovsson, C., 2021. Directed technical change as a response to natural resource scarcity. *Journal of Political Economy* 129, 3039–3072.
- Hendrickson, J.R., Salter, A.W., Albrecht, B.C., 2018. Preventing plunder: Military technology, capital accumulation, and economic growth. *Journal of Macroeconomics* 58, 154–173.
- Hosek, J., Asch, B.J., Mattock, M.G., Smith, T.D., 2018. Military and civilian pay levels, trends, and recruit quality. Technical Report. RAND Corporation.
- Ilzetzki, E., 2024. Learning by necessity: Government demand, capacity constraints, and productivity growth. *American Economic Review* 114, 2436–2471.
- Ilzetzki, E., 2025. Guns and growth: The economic consequences of defense buildups. Technical Report. Kiel Report.
- Jacquinot, P., Lozej, M., Pisani, M., 2018. Labor tax reforms, cross-country coordination, and the monetary policy stance in the euro area: A structural model-based approach. *International Journal of Central Banking* 14, 65–140.
- Leeper, E.M., Walker, T.B., Yang, S.C.S., 2010. Government investment and fiscal stimulus. *Journal of Monetary Economics* 57, 1000–1012.
- Lozej, M., Onorante, L., Rannenberg, A., 2023. Countercyclical capital regulation in a small open economy dsge model. *Macroeconomic Dynamics* 27, 1230–1267.
- Lucas, R.E., 1988. On the mechanics of economic development. *Journal of Monetary Economics* 22, 3–42.
- Mohr, C., Trebesch, C., 2025. Geoeconomics. *Annual Review of Economics* 17.
- NATO, 2025. Defence expenditures and NATO's 5% commitment. https://www.nato.int/cps/en/natohq/topics_49198.htm. Accessed: 2025-09-14.
- Nordhaus, W., 2019. Climate change: The ultimate challenge for economics. *American Economic Review* 109, 1991–2014.
- Pflueger, C., Yared, P., 2024. Global hegemony and exorbitant privilege. Technical Report. National Bureau of Economic Research.
- Ramey, V.A., Shapiro, M.D., 1998. Costly capital reallocation and the effects of government spending, in: *Carnegie-Rochester conference series on public policy*, Elsevier. pp. 145–194.
- Romer, P.M., 1986. Increasing returns and long-run growth. *Journal of Political Economy* 94, 1002–1037.
- SIPRI, 2025. SIPRI Arms Transfers Database, doi: <https://doi.org/10.55163/SAFC1241>.
- Smets, F., Wouters, R., 2007. Shocks and frictions in US business cycles: A Bayesian DSGE approach. *American Economic Review* 97, 586–606.
- Torres, J.L., 2020. The production of national defense and the macroeconomy. *PLoS One* 15, e0240299.

Valaitis, V., Villa, A.T., 2025. Optimal Fiscal Policy Under Endogenous Disaster Risk: How to Avoid Wars? London School of Economics and Political Science.

A Data used for the calibration of defence spending

One of the contributions of our analysis is our construction of a relatively long time series on military equipment (i.e. arms) trade that we use for the calibration of the model, in particular the imports and exports of arms. To do this, we have relied on data in the Arms Transfers Database collected by the Stockholm International Peace Research Institute (SIPRI). The creators of this database note that it was “not developed to assess the financial value of the international arms trade; rather, the trend-indicator value (TIV) data ... is designed to serve as an indicator of the volume of military equipment transferred in the world” (SIPRI, 2025). However, the calibration of our model (and, we suspect, empirical analysis of this data) requires a transformation of this volume index into financial value terms. SIPRI does provide an estimate of the financial value of the global arms trade, using the aforementioned database and a set of assumptions and approximations.³⁷

Their estimate, however, is only for the year 2022. As we cannot ascertain if 2022 is an outlier, a point at a peak or perhaps at a trough of the cycle, we need to construct a longer time series. Therefore, we used the current-dollar values of arms trade from 2001 (when the data on arms transfers in current USD start) to 2020 (the beginning of Covid and subsequent disruptions in global trade), and apply the methodology SIPRI used in making the 2022 estimate. We summarise this methodology below. The SIPRI makes the following assumptions when calculating the value of the global arms trade (parts of the text below we repeat verbatim from SIPRI):

- Where available, use figures for export deliveries for the current year.
- If export deliveries are not available for the current year, use the figures for arms export deliveries from the previous year.
- If neither of the above are available, use the full figure for arms export agreements, or orders from the previous year, if available.³⁸
- If none of the above are available, half of the figure for “arms export licences” in the current year is used, if available.
- For Canada, SIPRI has doubled the figures for arms export deliveries for 2022, as these excluded deliveries to the US, which, according to the Canadian government, account for more than half of exports of military technology. We have used the same principle for the entire sample.³⁹
- For Germany, we used export-license based estimates even though Germany reports arms export deliveries. This is because the latter only include deliveries of “war weapons”, which is a much more limited category.

³⁷This is available from <https://www.sipri.org/databases/financial-value-global-arms-trade>

³⁸SIPRI consider this a good indicator, based on past cases where countries have released data on both arms export deliveries and arms export agreements.

³⁹As Canada is a relatively small exporter of arms, this adjustment has no meaningful impact on the value of the global arms trade.

In addition, some of the values in SIPRI data are reported as $< X'$ or $> X$, where X is some number. In such cases, we took half of X where the number reported was in the format $< X$, and the full value of X where the number reported was in the format $> X$. Where the data are not available, we set the value to zero. We consider the numbers obtained in this way a conservative estimate of the actual arms exports. However, there are as plausible an estimate as are possible with the available data and thus not a result of a more or less arbitrary speculation regarding the extent of the arms trade. It is worth noting that our estimates are remarkably stable over time, when computed as a share of world GDP. We believe that this indicates, that despite omissions in some years, our estimated time series is not greatly affected by these omissions.

TABLE 3. Financial value of arms exports

| Country | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|------------------|-------|-------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Albania | 1 | 1 | 1 | 1 | 1 | 4 | 3 | 1 | 3 | 0 | 4 | 3 | 1 | 4 | 2 | 1 | 2 | 4 | 4 | 4 |
| Australia | 51 | 247 | 385 | 385 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 540 | 735 | 1580 | 416 | 609 | 1833 | 1844 | 926 |
| Austria | 173 | 41 | 131 | 5 | 141 | 182 | 170 | 308 | 483 | 494 | 598 | 585 | 698 | 712 | 373 | 707 | 428 | 352 | 381 | 485 |
| Belgium | 210 | 278 | 278 | 338 | 141 | 257 | 257 | 978 | 765 | 664 | 580 | 623 | 407 | 2994 | 618 | 691 | 418 | 687 | 1604 | 1694 |
| Bosnia and Herz. | 0 | 0 | 0 | 22 | 40 | 31 | 26 | 41 | 32 | 13 | 57 | 53 | 52 | 89 | 116 | 115 | 117 | 139 | 139 | 151 |
| Brazil | 290 | 167 | 49 | 285 | 285 | 352 | 160 | 38 | 99 | 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bulgaria | 0 | 0 | 0 | 0 | 177 | 141 | 203 | 220 | 201 | 342 | 321 | 281 | 312 | 535 | 1555 | 1122 | 1374 | 903 | 687 | 745 |
| Canada | 764 | 864 | 1034 | 990 | 531 | 635 | 607 | 1046 | 948 | 792 | 1281 | 2086 | 1323 | 1441 | 1057 | 1083 | 1587 | 3193 | 5662 | 2932 |
| Croatia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 72 | 49 | 66 | 114 | 95 | 43 | 82 | 77 | 116 | 48 | 81 |
| Cyprus | 0 | 0 | 0 | 0 | 0 | 8 | 1 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| Czechia | 55 | 72 | 94 | 112 | 109 | 117 | 238 | 278 | 243 | 287 | 254 | 352 | 382 | 567 | 624 | 762 | 646 | 693 | 767 | 719 |
| Denmark | 34 | 53 | 45 | 63 | 55 | 82 | 134 | 119 | 175 | 249 | 165 | 143 | 31 | 59 | 85 | 124 | 103 | 97 | 185 | 219 |
| Estonia | 0 | 0 | 0 | 0 | 1 | 1 | 4 | 9 | 4 | 1 | 4 | 1 | 1 | 4 | 4 | 4 | 2 | 1 | 3 | 7 |
| Finland | 36 | 51 | 55 | 52 | 128 | 66 | 103 | 136 | 121 | 78 | 135 | 75 | 296 | 296 | 109 | 146 | 118 | 151 | 127 | 91 |
| France | 2833 | 4169 | 4847 | 8843 | 4743 | 5061 | 6214 | 4648 | 4408 | 4935 | 5259 | 4854 | 4486 | 5367 | 6878 | 7875 | 7588 | 8222 | 11113 | 4911 |
| Germany | 1649 | 1533 | 2745 | 2364 | 2621 | 2628 | 2510 | 4239 | 3503 | 3148 | 3763 | 3022 | 3880 | 2636 | 4358 | 3787 | 3518 | 2847 | 4487 | 3320 |
| Greece | 23 | 24 | 63 | 9 | 36 | 110 | 45 | 70 | 70 | 195 | 157 | 218 | 218 | 0 | 0 | 0 | 0 | 78 | 57 | 112 |
| Hungary | 9 | 7 | 12 | 11 | 15 | 20 | 23 | 22 | 24 | 25 | 25 | 35 | 42 | 44 | 51 | 21 | 50 | 44 | 59 | 55 |
| Hungary | 0 | 23 | 94 | 70 | 58 | 95 | 83 | 198 | 69 | 69 | 0 | 86 | 117 | 163 | 321 | 226 | 718 | 1217 | 1295 | 114 |
| India | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Iran | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ireland | 24 | 17 | 20 | 10 | 17 | 19 | 31 | 19 | 19 | 16 | 19 | 30 | 41 | 57 | 24 | 35 | 14 | 6 | 2 | 14 |
| Israel | 2000 | 2000 | 2350 | 2600 | 2600 | 3000 | 3000 | 3297 | 6900 | 7200 | 7000 | 7470 | 7496 | 6635 | 5665 | 5761 | 6552 | 9374 | 7596 | 7299 |
| Italy | 496 | 458 | 711 | 596 | 1033 | 1217 | 1734 | 2603 | 3063 | 816 | 1422 | 3867 | 3680 | 4417 | 3564 | 3157 | 3247 | 2900 | 3564 | 55 |
| Korea, South | 0 | 200 | 144 | 241 | 418 | 262 | 253 | 845 | 1166 | 1166 | 1188 | 2382 | 2353 | 3416 | 3612 | 3541 | 2558 | 3120 | 2770 | 3080 |
| Latvia | 0 | 0 | 0 | 0 | 5 | 3 | 1 | 1 | 1 | 11 | 1 | 1 | 1 | 3 | 3 | 3 | 100 | 100 | 0 | 0 |
| Lithuania | 0 | 7 | 7 | 2 | 3 | 5 | 60 | 45 | 61 | 20 | 67 | 24 | 21 | 25 | 30 | 45 | 80 | 112 | 58 | 76 |
| Luxembourg | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 4 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 5 |
| Malta | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 4 | 10 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| Montenegro | 0 | 0 | 0 | 0 | 0 | 1 | 21 | 25 | 11 | 8 | 8 | 4 | 4 | 12 | 4 | 1 | 7 | 9 | 9 | 27 |
| North Macedonia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 7 | 1 | 1 | 14 | 6 | 6 | 0 |
| The Netherlands | 291 | 212 | 650 | 387 | 848 | 1014 | 1196 | 732 | 788 | 895 | 1073 | 1056 | 336 | 332 | 657 | 626 | 750 | 675 | 499 | 761 |
| Norway | 178 | 288 | 427 | 299 | 381 | 455 | 546 | 690 | 716 | 607 | 638 | 667 | 562 | 467 | 405 | 427 | 648 | 593 | 519 | 658 |
| Pakistan | 80 | 80 | 0 | 0 | 7 | 18 | 19 | 52 | 14 | 17 | 10 | 13 | 13 | 17 | 60 | 31 | 58 | 58 | 0 | 0 |
| Poland | 50 | 80 | 80 | 163 | 210 | 210 | 196 | 270 | 966 | 303 | 590 | 407 | 446 | 525 | 467 | 424 | 532 | 575 | 438 | 446 |
| Portugal | 10 | 6 | 28 | 15 | 9 | 22 | 1 | 104 | 22 | 26 | 35 | 40 | 234 | 208 | 212 | 660 | 183 | 248 | 439 | 203 |
| Romania | 25 | 44 | 69 | 42 | 46 | 100 | 84 | 122 | 136 | 163 | 182 | 107 | 235 | 211 | 179 | 200 | 218 | 230 | 161 | 132 |
| Russia | 3705 | 4820 | 5600 | 5780 | 6126 | 6500 | 7400 | 8350 | 8500 | 10000 | 13700 | 15200 | 15700 | 15600 | 14500 | 15000 | 15000 | 16000 | 16000 | 16000 |
| Serbia | 0 | 0 | 0 | 0 | 0 | 71 | 93 | 224 | 146 | 193 | 164 | 154 | 232 | 268 | 304 | 443 | 546 | 459 | 409 | 384 |
| Slovakia | 0 | 0 | 0 | 25 | 26 | 40 | 51 | 56 | 61 | 20 | 12 | 32 | 41 | 48 | 63 | 66 | 78 | 110 | 76 | 105 |
| Slovenia | 4 | 2 | 2 | 1 | 2 | 2 | 4 | 8 | 7 | 8 | 12 | 5 | 4 | 7 | 12 | 17 | 27 | 17 | 21 | 21 |
| South Africa | 202 | 243 | 410 | 424 | 424 | 428 | 568 | 714 | 922 | 1138 | 1265 | 1291 | 1390 | 1647 | 1655 | 1678 | 1739 | 2035 | 2741 | 2279 |
| Spain | 207 | 259 | 432 | 504 | 521 | 1060 | 1277 | 1368 | 1871 | 1494 | 3379 | 2509 | 5189 | 4250 | 4126 | 283 | 4900 | 357 | 4525 | 189 |
| Sweden | 296 | 353 | 801 | 992 | 1155 | 1406 | 1421 | 1927 | 1772 | 1907 | 2143 | 1441 | 1833 | 1160 | 884 | 1283 | 1314 | 1308 | 4525 | 4131 |
| Switzerland | 153 | 178 | 281 | 323 | 207 | 317 | 387 | 667 | 669 | 615 | 983 | 747 | 497 | 616 | 464 | 418 | 454 | 522 | 1721 | 1773 |
| Taiwan | 171 | 2161 | 323 | 173 | 164 | 9367 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 960 |
| Turkiye | 134 | 248 | 331 | 196 | 337 | 352 | 420 | 576 | 670 | 684 | 817 | 1200 | 1390 | 1647 | 1655 | 1678 | 1739 | 2035 | 2741 | 2279 |
| UK | 2207 | 1412 | 1620 | 2547 | 2529 | 2499 | 4142 | 4142 | 8010 | 11296 | 9007 | 8652 | 13893 | 15321 | 13996 | 11764 | 7961 | 11541 | 18676 | 14031 |
| Ukraine | 500 | 500 | 500 | 500 | 0 | 0 | 700 | 800 | 800 | 957 | 1004 | 1024 | 1000 | 1000 | 570 | 770 | 770 | 766 | 908 | 981 |
| USA | 5800 | 57000 | 59900 | 65600 | 75800 | 80700 | 78100 | 95200 | 114300 | 119100 | 142600 | 153900 | 151800 | 152800 | 158100 | 149800 | 153300 | 153300 | 112973 | 112910 |
| World total | 72660 | 78098 | 84546 | 94972 | 101952 | 118834 | 112486 | 135193 | 162795 | 170075 | 199978 | 214171 | 220233 | 225063 | 227548 | 218077 | 218663 | 229338 | 202620 | 183132 |

Notes: Source: SIPRI and authors own calculations. Government and industry data on the financial value of national arms exports. Millions of current USD. Rounded to last digit.

B Arms trade matrix

An important feature in our model, and in real life given the recent focus on strategic autonomy, is trade in arms. However, the data on such flows required to calibrate our model are not directly available. The only consistent dataset on bilateral arms trade flows is SIPRI's Arms transfers database. We use this database, along with the estimated financial value of arms trade described above, to quantify the bilateral arms trade flows. Here we describe in detail the necessary steps we took to achieve this.

SIPRI's Arms transfers database provides data on *quantities* of bilateral arms transfers. These are not values, but indices of quantity (TIV - trend-indicator value), designed to indicate the volume of arms transfers.⁴⁰ We first compute these quantities on a bilateral basis for all blocs of the model. Because two of the blocs represent groups of countries (the rest of the euro area and the rest of the world), we must exclude intra-bloc arms trade.⁴¹ We then calculate the bilateral arms flows between the blocs. Although this provides us with the bilateral shares in total arms imports, it is in terms of quantity shares.

As quantity shares do not account for different prices or quality of arms, we must correct for this deficiency. First, we note that in terms of quantities, US arms exports in the period 2001-2020 averaged 32.3% of global arms exports. However, in value terms they were 69.2%.⁴² This implies that the price of US arms exports more than double the average price of global arms exports, highlighting the need to make these adjustments. We follow the same procedure for the other blocs in our model and report the results in Table 4.

TABLE 4. Relative prices of arms exports

| Country/bloc | Share in quantity terms | Share in value terms | Implied relative price |
|--------------|-------------------------|----------------------|------------------------|
| DE | 6.6 | 2.0 | 0.35 |
| REA | 14.9 | 7.9 | 0.54 |
| US | 32.3 | 69.2 | 2.18 |
| RW | 46.1 | 20.8 | 0.47 |

Notes: Source: SIPRI. Averages 2001-2020, the aggregate price is normalised to one. Totals may not add up due to rounding.

We use the resulting relative prices to multiply the bilateral quantity shares, which gives us the bilateral arms trade matrix reported in Table 1 in the main text. This table is to be read by columns. For example, the second column (DE) reports that the share of arms imports from the REA in the total arms imports of Germany is 20.25%, the share of arms imports from the US is 62.58%, and the share of arms imports from RW is 17.17%. The reported numbers are the averages for the period 2001-2020, consistent with the period used to estimate the total value of arms trade reported above. The import shares in this table are targets that we match by calibrating the parameters of the arms imports aggregators.

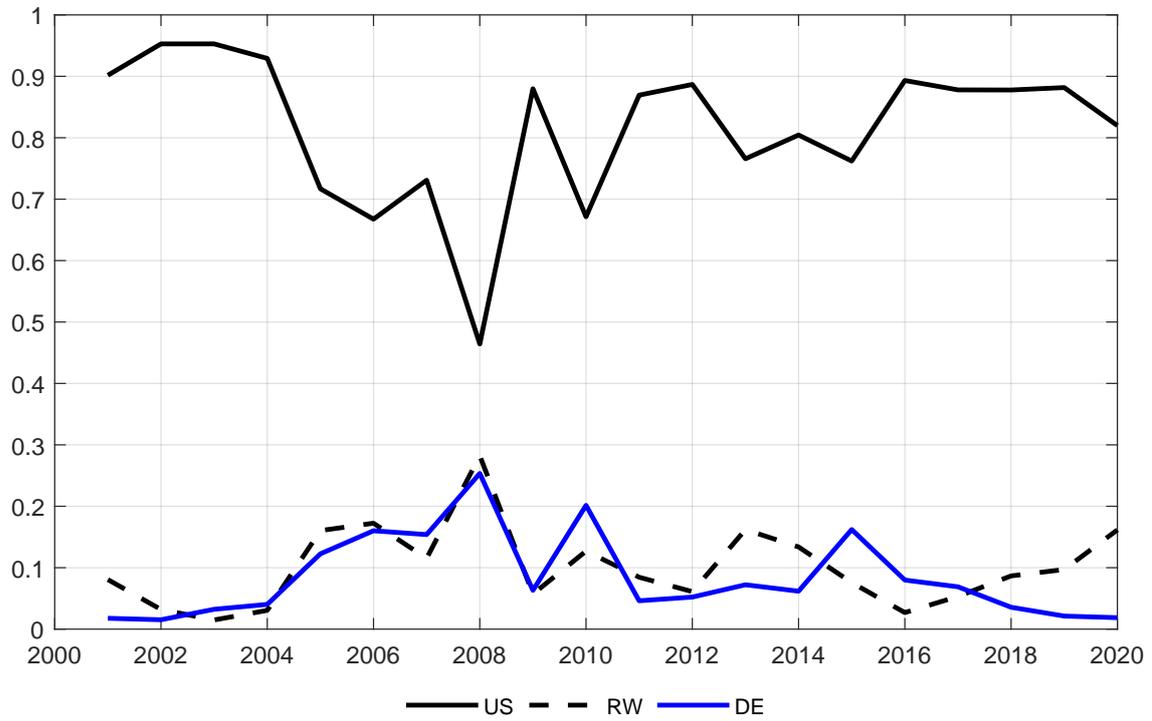
⁴⁰The interested reader can find more information on this in SIPRI (2025)

⁴¹We include Denmark in the REA, as its currency is irrevocably pegged to the euro.

⁴²We compute these numbers based on total arms trade, i.e., we do not exclude bilateral arms trade within the REA and RW bloc.

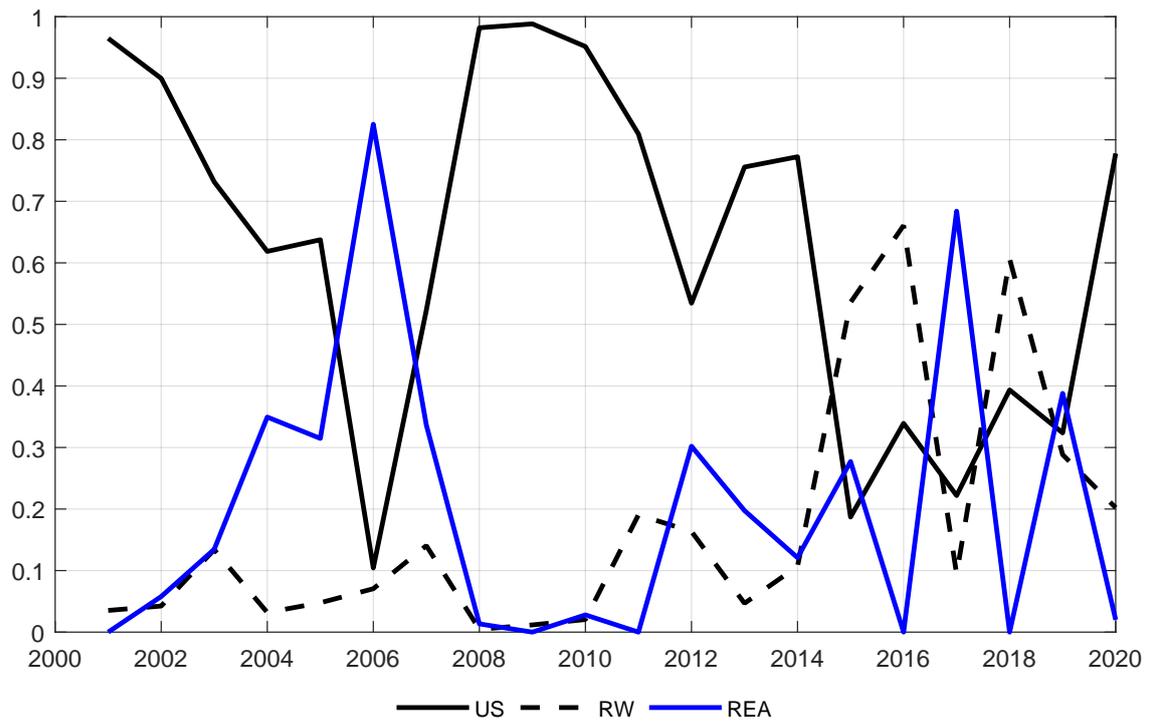
In Figures 16 to 18 we demonstrate that the shares of arms trade are relatively stable over time. This is especially the case for the three larger blocs. The main trading partner is the US (and for the US, it is the RW). This is in line with the numbers provided by The Global Economy, where the US accounts for about 70% of global arms exports in the period from 2001-2020.

FIGURE 15. Bilateral shares of REA arms imports



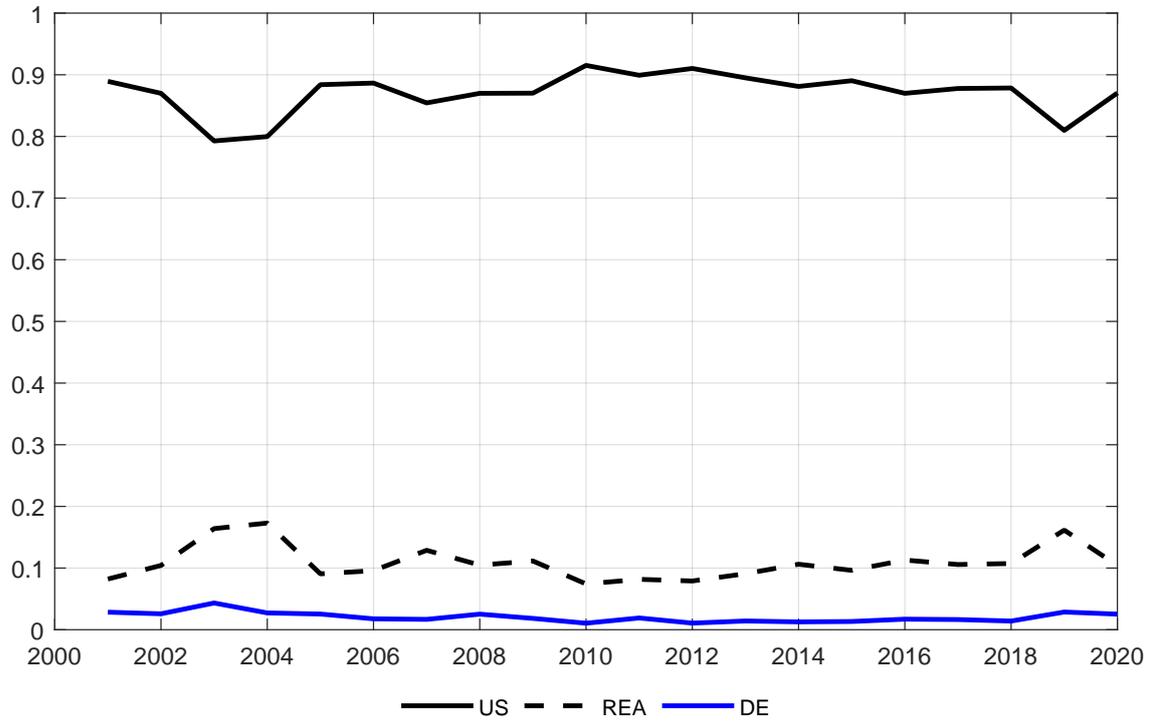
Notes: Authors own calculations.

FIGURE 16. Bilateral shares of DE arms imports



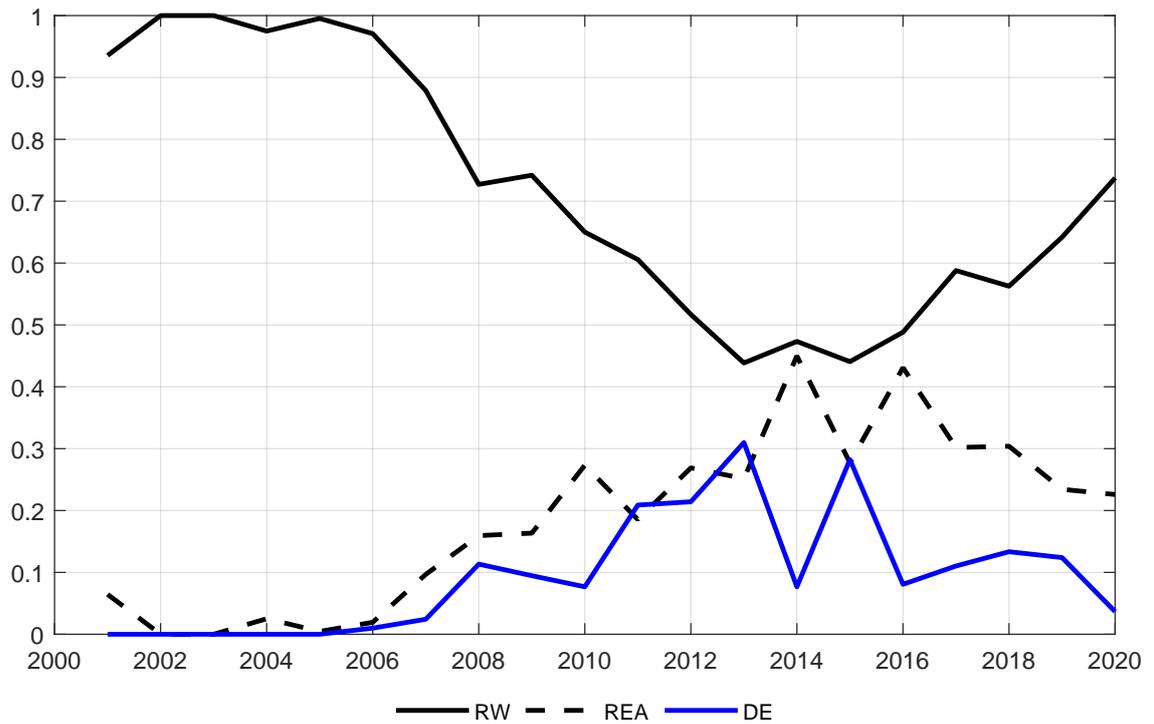
Notes: Authors own calculations.

FIGURE 17. Bilateral shares of RW arms imports



Notes: Authors own calculations.

FIGURE 18. Bilateral shares of US arms imports



Notes: Authors own calculations.

C Calibration tables

TABLE 5. Steady-State National Accounts (Ratio to GDP, %)

| | DE | REA | US | RW |
|--|-------|-------|-------|-------|
| Domestic demand | | | | |
| Private consumption | 46.9 | 56.4 | 66.1 | 54.9 |
| Private investment | 16.25 | 17.41 | 17.20 | 19.25 |
| Public consumption | 18.80 | 23.00 | 19.40 | 20.60 |
| Public investment | 3.0 | 3.0 | 3.0 | 3.0 |
| Trade | | | | |
| Imports (total) | 75.7 | 23.5 | 13.8 | 9.3 |
| Imports of consumption goods | 29.2 | 12.7 | 9.5 | 3.9 |
| Imports of investment goods | 9.6 | 4.4 | 3.0 | 2.4 |
| Imports of exports | 37.0 | 6.4 | 1.3 | 2.4 |
| Net foreign assets (ratio to annual GDP) | -20.0 | -0.1 | - | -3.0 |
| Share of world GDP | 0.026 | 16.44 | 22.6 | 60.7 |

Note: DE=Germany; REA=Rest of the euro area; US=United States; RW=Rest of world

D Implementation of permanent shocks

In the paper, unless stated otherwise, we study the effect of permanent shocks, i.e., a transition from the initial to the final steady state. We do so by first calibrating the model to match the initial, pre-policy-change steady state, as discussed in the calibration section. Then, we change the exogenous variables that are changed by policy measures, and we treat all other parameters as deep parameters (i.e., we do not recalibrate change them). This implies that all the quasi-shares and technological parameters after the policy change remain the same as before the policy change. The Great Ratios, prices, etc. are left to change endogenously. The only exceptions to this are fixed cost and the fiscal rule, as we describe below.

The fiscal rule stabilises the debt-to-GDP ratio in the steady state at 60% of annual GDP by levying lump-sum taxes on Ricardian households (this is the most neutral tax measure). Because we assume that the defence spending (of all types) is debt-financed, we adjust the level of lump-sum taxes in the final (post-policy-change) steady state so that the debt-to-GDP remains at 60%.

Fixed costs in production, ψ_D , ψ_T and ψ_N (see equations 7, 10, and 11) are set so that profits are zero in the steady state, consistent with the notion that there should be no free entry of firms in the steady state. We keep this convention also in the final steady state and gradually adjust the fixed costs to the new post-policy-change steady state.

Because we have a transition between two steady states, the level of output and relative prices change. This raises an issue of how the potential output should be computed, concretely, at which prices should GDP components from various sectors be added together to compute the aggregate output. To address this issue, we follow Coenen et al. (2024) and assume that prices used to compute potential GDP move gradually to new level following an AR(1) process with the persistence of 0.98. Similarly,

TABLE 6. Calibration of households and firms

| | DE | REA | US | RW |
|--|--------|--------|--------|--------|
| Households | | | | |
| Discount factor (β) | 0.9975 | 0.9975 | 0.9975 | 0.9975 |
| Intertemporal elasticity of substitution (σ^{-1}) | 2.00 | 2.00 | 2.00 | 2.00 |
| Habit persistence (κ) | 0.6 | 0.6 | 0.6 | 0.6 |
| Capital depreciation rate (δ^K) | 0.025 | 0.025 | 0.025 | 0.025 |
| Share of non-Ricardian households (ω) | 0.25 | 0.25 | 0.25 | 0.25 |
| Interm.-good firms (trad. and non-trad. sectors) | | | | |
| Subst. btw. labour and capital | 1.00 | 1.00 | 1.00 | 1.00 |
| Bias towards capital - tradables (α_T) | 0.30 | 0.30 | 0.30 | 0.30 |
| Bias towards capital - non-tradables (α_N) | 0.30 | 0.30 | 0.30 | 0.30 |
| Production - labour services (α_H) | 0.99 | 0.99 | 0.99 | 0.99 |
| Final consumption-good firms | | | | |
| Subst. btw. domestic and imported trad. goods (μ_{TC}) | 2.50 | 2.50 | 2.50 | 2.50 |
| Bias towards domestic tradable goods (ν_{TC}) | 0.29 | 0.46 | 0.62 | 0.69 |
| Subst. btw. tradables and non-tradables (μ_C) | 0.50 | 0.50 | 0.50 | 0.50 |
| Bias towards tradable goods (ν_C) | 0.80 | 0.45 | 0.35 | 0.35 |
| Bilat. bias towards imported goods, Home (ν_{MC}) | - | 0.26 | 0.11 | 0.63 |
| Bilat. bias towards imported goods, REA (ν_{MC}) | 0.08 | - | 0.10 | 0.82 |
| Bilat. bias towards imported goods, US (ν_{MC}) | 0.04 | 0.13 | - | 0.83 |
| Bilat. bias towards imported goods, RW (ν_{MC}) | 0.04 | 0.61 | 0.35 | - |
| Substitution btw. consumption good imports (μ_{IMC}) | 2.50 | 2.50 | 2.50 | 2.50 |
| Final investment-good firms | | | | |
| Subst. btw. domestic and imported trad. goods (μ_{TI}) | 2.50 | 2.50 | 2.50 | 2.50 |
| Bias towards domestic tradable goods (ν_{TI}) | 0.40 | 0.76 | 0.71 | 0.56 |
| Substitution btw. tradables and non-tradables (μ_I) | 0.50 | 0.50 | 0.50 | 0.50 |
| Bias towards tradable goods (ν_I) | 0.80 | 0.75 | 0.75 | 0.75 |
| Bilat. bias towards imported goods, Home (ν_{MI}) | - | 0.18 | 0.42 | 0.40 |
| Bilat. bias towards imported goods, REA (ν_{MI}) | 0.04 | - | 0.23 | 0.73 |
| Bilat. bias towards imported goods, US (ν_{MI}) | 0.05 | 0.17 | - | 0.78 |
| Bilat. bias towards imported goods, RW (ν_{MI}) | 0.01 | 0.53 | 0.46 | - |
| Substitution btw. investment good imports (μ_{IMI}) | 2.50 | 2.50 | 2.50 | 2.50 |
| Reexported goods | | | | |
| Subst. btw. dom. tradables and imported exports (μ_X) | 1.50 | 1.50 | 1.50 | 1.50 |
| Bias towards domestic tradable goods in exports (ν_X) | 0.50 | 0.62 | 0.82 | 0.63 |
| Bilat. bias towards imported goods, Home (ν_{MX}) | - | 0.25 | 0.19 | 0.56 |
| Bilat. bias towards imported goods, REA (ν_{MX}) | 0.08 | - | 0.13 | 0.79 |
| Bilat. bias towards imported goods, US (ν_{MX}) | 0.06 | 0.14 | - | 0.80 |
| Bilat. bias towards imported goods, RW (ν_{MX}) | 0.03 | 0.58 | 0.38 | - |
| Substitution btw. goods in import bundle (μ_{MX}) | 2.50 | 2.50 | 2.50 | 2.50 |

Note: DE=Germany; REA=Rest of euro area; US=United States; RW=Rest of world

TABLE 7. International Linkages (Trade Matrix, Share of Domestic GDP, %)

| | DE | REA | US | RW |
|---------------------------------|------|------|------|------|
| Consumption-good imports | | | | |
| Total consumption good imports | 29.2 | 12.7 | 9.5 | 3.9 |
| <i>From partner</i> | | | | |
| DE | - | 0.5 | 0.2 | 0.1 |
| REA | 6.4 | - | 1.0 | 2.4 |
| US | 2.8 | 1.0 | - | 1.4 |
| RW | 20.0 | 11.2 | 8.3 | - |
| Investment-good imports | | | | |
| Total investment good imports | 9.6 | 4.4 | 3.0 | 2.4 |
| <i>From partner</i> | | | | |
| DE | - | 0.08 | 0.01 | 0.01 |
| REA | 1.6 | - | 0.5 | 1.3 |
| US | 3.5 | 0.8 | - | 1.1 |
| RW | 4.5 | 3.5 | 2.5 | - |
| Imports of exports | | | | |
| Total imports of exports | 37.0 | 6.4 | 1.3 | 2.4 |
| <i>From partner</i> | | | | |
| DE | - | 0.25 | 0.00 | 0.06 |
| REA | 7.8 | - | 0.2 | 1.2 |
| US | 6.2 | 0.7 | - | 1.2 |
| RW | 23.0 | 5.4 | 1.1 | - |

Note: DE=Germany; REA=Rest of the euro area; US=United States; RW=Rest of world

TABLE 8. Price markups (elasticities of substitution)

| | Tradables (θ_T) | Non-tradables (θ_N) | Imports of exports (θ_X) |
|-----|--------------------------|------------------------------|-----------------------------------|
| DE | 1.20 (6.0) | 1.50 (3.0) | 1.30 (4.3) |
| REA | 1.20 (6.0) | 1.50 (3.0) | 1.30 (4.3) |
| US | 1.20 (6.0) | 1.28 (4.6) | 1.20 (6.0) |
| RW | 1.20 (6.0) | 1.28 (4.6) | 1.20 (6.0) |

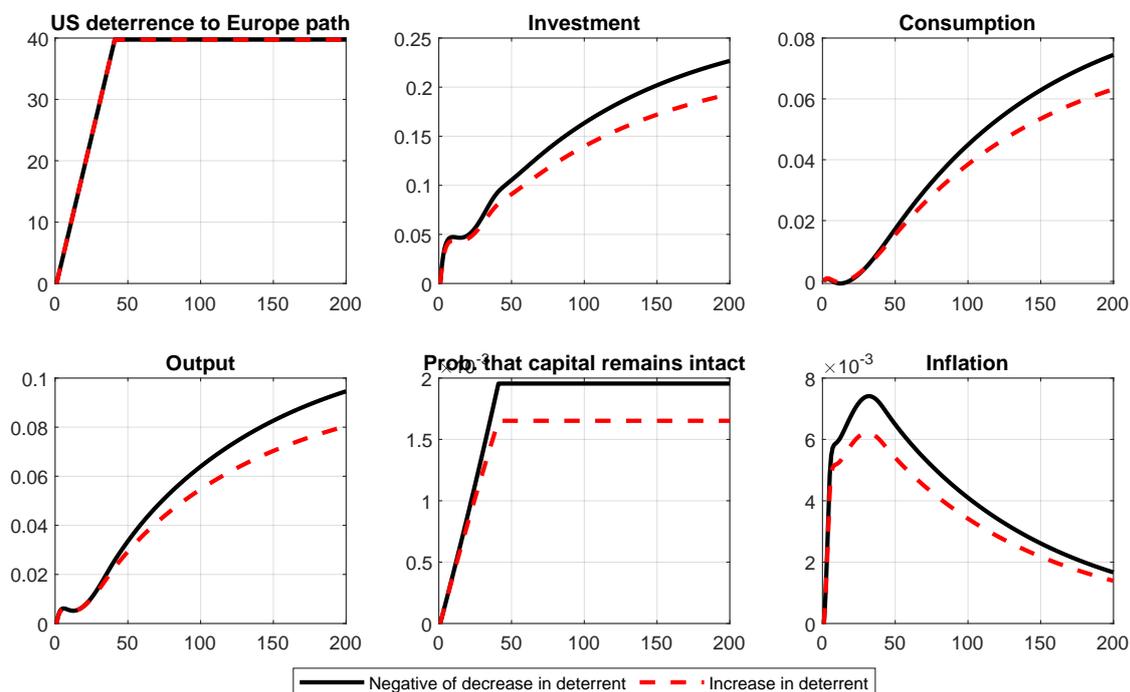
Note: DE=Germany; REA=Rest of the euro area; US=United States; RW=Rest of world

we follow Coenen et al. (2024) and use the deviation of quarterly real GDP growth from potential growth in the monetary policy rule.

E Asymmetry in deterrence

In the main text, we mention the asymmetry of the function shown in Figure 1, which arises from equations 4. This asymmetry is important because it implies that increases in the amount of deterrent will have diminishing effects, because the function in Figure 1 becomes increasingly flat as the level of deterrent increases. Here we show that this is indeed the case by plotting two cases in Figure 19. The first case, shown in full black lines, is the negative of the US decrease in provision of deterrent to Europe (this is identical to the lines shown in Figure 3, multiplied by -1). The second case, shown in dashed red lines, is an identical shock, with an identical path, just that its sign is reversed, i.e., the US increases its provision of deterrent to Europe. The shock size and path are therefore identical, just with opposite signs, and after multiplying the decrease in US deterrent with -1 the trajectories of both shock lie on top of each other, as shown in the top-left panel in Figure 19. The paths of other variables, however, are not identical. In particular, the effects of an increase (shown in dashed red lines) are smaller than the effects of the decrease (multiplied by -1). The reason is that an increase moves the economy towards the flatter part of the S-shaped curve shown in Figure 1, which results in smaller effects than the move in the opposite direction, which would bring the economy towards a steeper part of the curve. It is this asymmetry that allows us to argue that an ever-increasing provision of deterrents is not a good idea, as its effects will become negligible. This explains why countries do not invest in defence deterrents beyond certain level, and why an ever-increasing investment in defence deterrents is not an optimal choice.

FIGURE 19. Asymmetry in deterrence effects

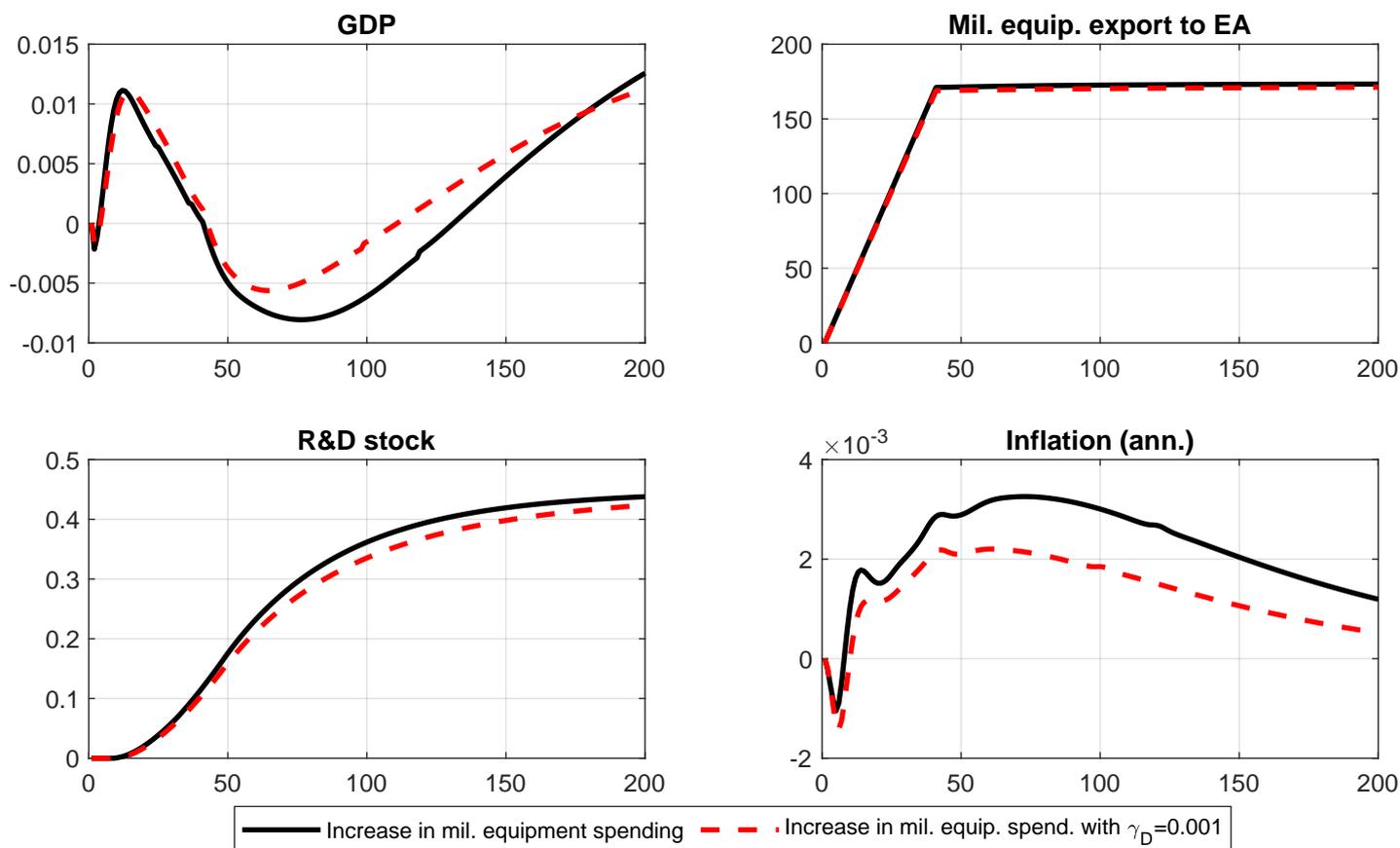


Notes: Euro area responses to a negative of a permanent decrease in the share of the US contribution to European deterrence by 20 p.p., along with the identically-sized increase. The responses are percent deviations from initial steady state, except the probability and inflation (annualised), which are in percentage point deviations.

F International spillovers

While the focus of our paper is not on international spillovers, the model itself does incorporate the fact that these spillovers exist, both between the euro area and the US and RW, and within the euro area blocs. To illustrate this issue, we focus on military equipment spending in Europe, which, due to a large import-content of this spending, affects somewhat the US variables. This is in particular the case if the R&D channel in the model is active, as a significant import content of European military equipment is imported from the US (see Table 2), which means that the R&D benefits of such purchases in Europe accrue to a large extent to the US. Figure 20 shows the effect of such policy on some of the main US variables. The spillovers are very small, despite the substantial increase in military equipment exports to Europe. Over the long run, US GDP increases by about 0.02% and the R&D stock by about 0.4%. Both of these reflect in large part the fact that the (official) global arms trade is relatively small compared to private trade, and that even a large increase of a small component of trade (i.e., military exports to EA) and the associated R&D spillovers do not play a material role. Note also that the responses are very similar in both cases shown, with high productivity of R&D (black line) or with this channel shut down (red dashed line). The only difference in the long run is that GDP increases somewhat more if the R&D is more productive.

FIGURE 20. Permanent increase in euro area defence equipment spending, spillovers to the US



Notes: Responses to a permanent increase in defence equipment spending in the euro area. The responses are percent deviations from initial steady state, except inflation, which is in annualised percentage point deviations.

